Empirical Methods for the Analysis of the Energy Transition

Day 4

Prof. Mar Reguant

Summer School 2023

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Demand side policies evaluation

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Electricity demand

- Electricity demand has been plateauing due to energy efficiency improvements.
- But it is **expected to grow considerably** as we electrify more areas of the economy (e.g., cars).
- Electricity demand is generally quite **inelastic and unresponsive**, but that does not go well with renewables or the current energy crisis...

Electricity is an essential input and difficult to substitute

Demand and the energy transition

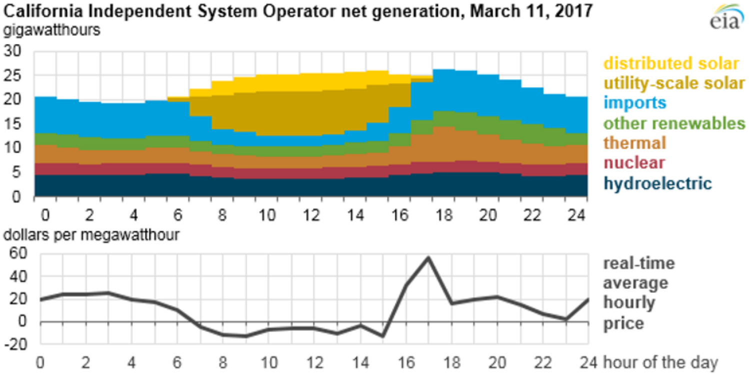
- We have been focusing so far on the supply side of the energy transition:
  - Wind and solar power integration
  - Climate policies to tax emissions
  - Transmission expansion
- Demand also needs to play a crucial role in our **need to reduce emissions** in a path to net zero.
  - Reduction of demand
  - Flexibility of demand
  - Participation of demand

How can demand policies help?

- Reducing demand directly contributes to lowering our emissions.
- Making demand more flexible can also be extremely valuable.
  - Shifting demand to when cleaner technologies are available.
  - It also makes energy cheaper (e.g., shift to solar).
- Even more important in moments of extreme conditions (e.g., high system pressure, risk of blackouts) (e.g., see Ito, Ida, Tanaka (2018)).

Electricity demand and renewables

Response even more important when there is a lot of renewable energy!



Energy demand: several response margins

We will separate between two strategies:

- **Energy efficiency**: becoming better at consuming the same goods, e.g., LEDs, building retrofit, better appliances, etc.
- **Demand response**: reducing our consumption if prices are high.

Today we will discuss demand response via pricing. All of these interact with technology adoption, electrification, and distributed energy adoption.

Energy efficiency vs demand response

- **Demand response**:
  - Getting consumers to change their behavior (when to consume and how much) as a response to a "signal".
  - Smart appliances/thermostats crucial to enable demand response.
- *Important!* Demand response might induce consumers to engage in energy efficiency as well.
  - Example: someone consumes a lot of electricity at peak times because of washing machine consumption.
  - If shifted to real-time prices, decide to shift demand, or decide to buy a more efficient appliance (or automatic).

Demand response

- Demand response programs are intended to **increase the elasticity of demand**.
- This response should help balance supply and demand.
  - "Demand follows supply" vs.
  - "Supply follows demand"
- Well known properties of **dynamic pricing** (e.g., Borenstein and Holland, 2005):
  - 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.

Electricity metering pre-XXI

- Electricity was (and still is in many places) metered only once a month, as water and gas.
- Difficult to imagine how consumers should respond to prices, if we do not even know how much they consume!
- Some utilities experimented with time-varying prices of electricity.
  - However, it had to be based on “representative” load curve for the neighborhood or for that kind of consumer

Smart meters

- Nowadays, there is a substantial push and rollout of smart meters.
- These meters enable collection of real-time electricity consumption data (typically every 15 minutes).
- The "economics" of smart meters
  - In some areas, they pay for themselves due to the savings in metering "by-hand"
  - In addition, they can provide added services like individualized pricing as well as technical services (voltage control)

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“Smart” pricing

- Smart meters unable a more tailored approach to electricity pricing.
- Different pricing formulas:
  - Flat tariff (most common, traditional)
  - Time-of-use pricing
  - Critical peak pricing
  - Real-time pricing
  - Non-price interventions (not necessarily smart)

TOU pricing

- This type of pricing model is similar to time-based telephone or internet plans.
- Depending on the hour of the day, the day of the week or the season, there is a schedule of pre-arranged prices.
- These prices tend to be fixed by hour, so the prices are far from being in "real-time".
- Yet, it can get consumers to engage in time-shifting behavior.
  - E.g., put washing machine at night

Critical peak pricing

- This type of intervention is implemented to get consumers to respond during extreme events.
  - Typically, extremely hot days in which air conditioning brings up electricity consumptions to very high levels
- Consumers agree to get really high prices on at most 10 critical peak events per summer.
- In compensation, they get a discount.
- Limitations: gets larger responses in critical days, but it only harvests responses in few events.

Real-time pricing

- In its most extreme form, consumers pay the wholesale price of electricity (plus the additional surcharges for distribution, taxes).
- Consumers fully internalize the conditions in the market (at least in theory).
- It implies that they can be made aware of:
  - Demand conditions
  - Renewable and other supply availability
  - Carbon/NOx/SO2 costs if pollution prices in the market

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Behavioral interventions

- Real-time pricing or time-of-use not always available, and often limited consumer engagement.
- Behavioral interventions attempt to engage residential consumers in a non-price manner.
  - Convince them that their effort is important to the system (e.g., post-Fukushima in Japan)
  - Show them how other neighbors are doing
  - Create competitions (e.g., in dorms where students don't see their electricity bill at the individual level)

Demand response: Theory and Empirics

Demand response: a large and growing literature

- Large **theoretical literature**: Borenstein (2005), Joskow and Tirole (2006, 2007), Borenstein and Holland (2005)...
- **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.

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Implications of real-time pricing

- Real-time pricing has short run effects:
  - Shifts demand from high price times
- In the long run, it also has implications for the generation mix.
  - The long run implications between TOU and real-time can be quite different (Borenstein, 2005)
- In the peak-load pricing model:
  - Avoid investments for extreme outcomes.
  - Reduces need for batteries in transition.
  - Disciplines market power.

Borenstein and Holland (2005)

- Consider a market with a share of sensitive consumers (pay wholesale RTP price) and a share of insensitive consumers (pay constant price).

$$\tilde{D}_t(p_t, \overline{p}) = \alpha D_t(p_t) + (1 - \alpha) D_t(\overline{p})$$

- Insensitive demand can be “too high”’ ’ or “too low”.
- Theory + “toy” simulations

- *What are the long-run inefficiencies from mispricing? What is the second best policy?*

On the efficiency of competitive electricity markets with time-invariant retail prices

Severin Borenstein*

and

Stephen Holland**

Most customers in electricity markets do not face prices that change frequently to reflect changes in wholesale costs, known as real-time pricing (RTP). We show that not only does time-invariant pricing in competitive markets lead to prices and investment that are not first best, it even fails to achieve the constrained second-best optimum. Increasing the share of customers on RTP is likely to improve efficiency, though surprisingly it does not necessarily reduce capacity investment, and it is likely to harm customers that are already on RTP. Simulations demonstrate that the efficiency gains from RTP are potentially quite significant.

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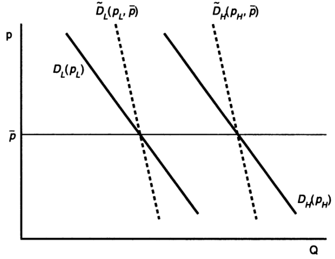
Borenstein and Holland (2005) – Main Results

- Thm 1. Pricing insensitive at weighted average price only optimal with constant elasticity. Second-best rate can be higher or lower.
- Thm 2. A subsidy or a tax can bridge the second-best gap.
- Thm 3. More consumers on RTP decreases long-run average prices.
- Thm 4. Capacity can go either way (but will tend to decrease with more RTP).

FIGURE 1
WHOLESALE DEMAND CURVES WITH AND WITHOUT SOME CUSTOMERS ON FLAT RATES



Borenstein (2005)

- Very similar to previous paper (some parts the same) but adding time-of-use to comparisons
- *Is TOU good enough?*

The Long-Run Efficiency of Real-Time Electricity Pricing

*Severin Borenstein**

Retail real-time pricing (RTP) of electricity – retail pricing that changes hourly to reflect the changing supply/demand balance – is very appealing to economists because it "sends the right price signals." Economic efficiency gains from RTP, however, are often confused with the short-term wealth transfers from producers to consumers that RTP can create. Abstracting from transfers, I focus on the long-run efficiency gains from adopting RTP in a competitive electricity market. Using simple simulations with realistic parameters, I demonstrate that the magnitude of efficiency gains from RTP is likely to be significant even if demand shows very little elasticity. I also show that "time-of-use" pricing, a simple peak and off-peak pricing system, is likely to capture a very small share of the efficiency gains that RTP offers.

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Borenstein (2005) – Main Results

- RTP welfare gains >> TOU.
- Note: Some of the TOU rates are very high and the model breaks down if consumers elastic enough.

Table 6: Welfare Effects of RTP versus TOU Pricing

A	B	C	D	E	F
Elasticity	Share on RTP/TOU	ANNUAL TOTAL SURPLUS CHANGE VS FLAT RATE			
		RTP	"Quasi-wholesale" TOU	Actual TOU price ratios	"Cost-share" TOU
-0.025	0.333	112,060,365	16,269,127	10,657,394	6,928,165
-0.025	0.666	205,800,109	32,538,254	21,314,789	13,856,330
-0.025	0.999	271,333,946	48,807,381	31,972,183	20,784,495
-0.050	0.333	196,836,537	32,226,253	21,322,177	13,683,652
-0.050	0.666	314,219,558	64,452,506	42,644,355	27,367,305
-0.050	0.999	388,316,857	96,678,759	63,966,532	41,050,957
-0.100	0.333	302,262,176	N/A	42,006,103	26,159,344
-0.100	0.666	439,987,363	N/A	84,012,206	52,318,689
-0.100	0.999	537,284,137	N/A	126,018,309	78,478,033
-0.150	0.333	370,238,483	N/A	61,775,434	37,387,646
-0.150	0.666	530,960,593	N/A	123,550,868	74,775,291
-0.150	0.999	647,620,518	N/A	185,326,302	112,162,937
-0.300	0.333	509,388,631	N/A	N/A	65,167,555
-0.300	0.666	730,577,275	N/A	N/A	130,335,110
-0.300	0.999	888,877,347	N/A	N/A	195,502,666
-0.500	0.333	641,472,723	N/A	N/A	92,710,676
-0.500	0.666	922,328,312	N/A	N/A	185,421,352
-0.500	0.999	1,098,811,460	N/A	N/A	278,132,028

Demand response as a solution?

- Questions on the **real possibilities**:
  - Electricity demand quite inelastic (0.1-0.3).
  - Even long-run estimates appear to be in inelastic range, -0.8 to -0.4.
  - Consumers typically exposed to constant electricity prices.
  - Even if consumers face real-time prices, they might not have the willingness to respond, or they might not even be at home.
  - If exposed to **dynamic pricing**, will consumers respond?
- Several studies examine how they respond to their average price of electricity, but response typically still limited.

Real-time pricing and experiments

A large part of the literature implements experiments of dynamic pricing.

Studies are performed in conjunction with the utilities, who have an interest in understanding the implications of these policies.

Typical design:

- Identify a target population
- Encourage switching to real-time to treatment group
- Compare encouraged group to the rest

Difficulties with experiments

- Encouragement of real-time pricing can have limited adoption in a baseline population.
- **Alternative design**:
  - Identify a target population that wants to adopt real-time pricing
  - Randomize who actually gets real-time pricing
  - Compare treatment group to control
- Limited external validity: How applicable is it for people who do not want real-time pricing?
- Some researchers have managed to default everyone on a dynamic tariff, much more effective (Fowlie et al., 2021).

Two examples

- Jessoe and Rapson (2015)
  - Look at the importance of information provision to achieve demand response
- Allcott and Rogers (2014)
  - Look at the importance of social comparisons to achieve demand response
  - Examine long-run persistence of the effects

Jessoe and Rapson (2015)

- What does the paper do?
  - Estimate demand responses when consumers see simple information
  - Based on a randomized control trial under different informational treatments
- What does the paper find?
  - Informed households are three standard deviations more responsive to temporary price increases
  - Conservation extends beyond pricing events

Research Design

- RCT with utility in Connecticut during July and August of 2011 (peak electricity demand).
- Encouragement across all costumers, intervention focused on those who decide to participate.
- Treatments:
  - Control. 207 households.
  - Price only. 130 households. Notification day prior to high price event (0.50)$andthirtyminutesprior$(1.25).
  - Price + IHD. 100 households. Same as price plus real-time information about electricity use and price.

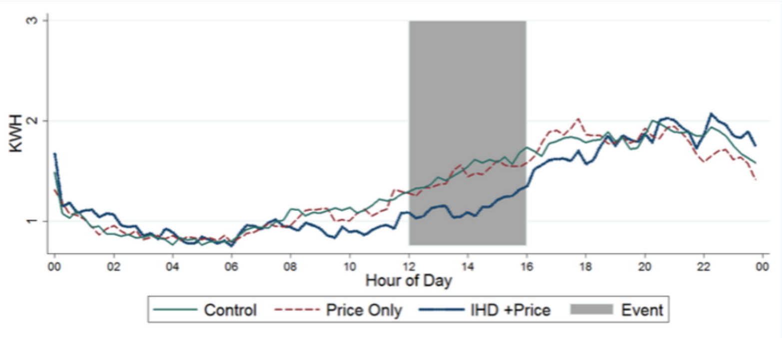
Main Results

Table 5—Treatment Effects (*Unbalanced Panel*)

Event type:	All (1)	All (2)	All (3)	All (4)	Day ahead (DA) (5)	30min (TM) (6)
Panel A. ITT unbalanced panel						
Price-only	−0.031	−0.054	−0.027	−0.038	−0.071*	0.006
	(0.036)	(0.036)	(0.036)	(0.036)	(0.042)	(0.044)
Price + IHD	−0.116**	−0.137***	−0.123***	−0.137***	−0.171***	−0.084
	(0.048)	(0.048)	(0.047)	(0.046)	(0.051)	(0.057)
Prob($P = P + I$)	0.096*	0.098*	0.051*	0.044**	0.066*	0.130
R^2	0.001	0.054	0.536	0.583	0.583	0.583
Panel B. ToT unbalanced panel						
Price-only	−0.032	−0.056	−0.028	−0.040	−0.074*	0.007
	(0.037)	(0.037)	(0.037)	(0.037)	(0.044)	(0.046)
Price + IHD	−0.143**	−0.170***	−0.153***	−0.170***	−0.217***	−0.100
	(0.058)	(0.058)	(0.057)	(0.057)	(0.064)	(0.067)
Prob($P = P + I$)	0.061*	0.052*	0.030**	0.023**	0.025**	0.115
R^2	0.001	0.054	0.536	0.583	0.583	0.583
HH FEs	No	No	Yes	Yes	Yes	Yes
Hour-by-day FEs	No	Yes	No	Yes	Yes	Yes
Number of events	6	6	6	6	3	3
Number of HHs	437	437	437	437	437	401

Main Results

Figure 6: August 26, 2011: 4hr \$0.50 increase, day-ahead notice



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Additional Results

- Effect of price and price + IHD most pronounced if consumers confirmed receipt.
- Otherwise, insignificant although still negative for IHD.
- Learning and experience seem to play a role, habit formation implies savings in other hours.
- Consumers who experience more with IHD appear to be most responsive.
  - Potential for unobserved heterogeneity
- Important follow-up work shows that response is "medium-rum" (not immediate). One needs technology for truly rapid response (Bollinger and Hartman, 2021).

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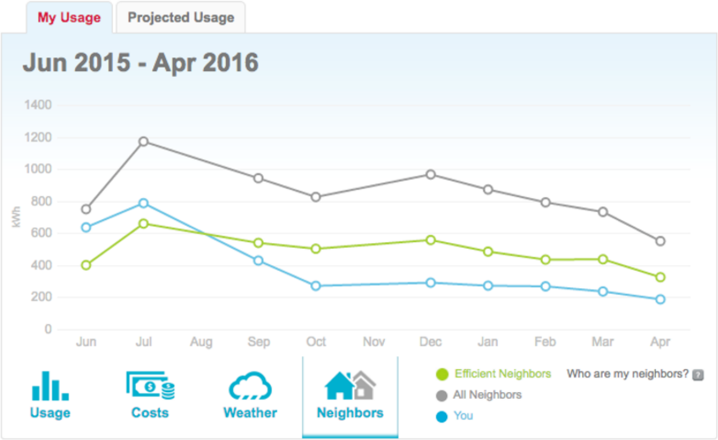
Allcott and Rogers (2014)

- What does the paper do?
  - Look at responses of consumers to a behavioral intervention (comparison to neighbors)
  - Look at three different climatic areas
  - Analyze data over an extended period of time
- What does the paper find?
  - Initial effects are large given limited intervention
  - "Action and backsliding", but persistent effects
  - Consumers respond even after two years

Smart meters and social comparisons



Research Design

Site:	(1)	(2)	(3)
Region	Upper midwest	Northwest	Southwest
Average January heating degrees	46.9	25.4	19.3
Average July cooling degrees	5.6	2.2	8.9
Narrative			
Baseline period begins	October 2007	January 2007	April 2006
First reports generated	January and February 2009	October 2008	March to May 2008
Last report generated for dropped group	January 2011	September 2010	June 2010
End of sample	April 2013	March 2013	March 2013
Frequency			
	60 percent monthly 40 percent quarterly (Randomly assigned) Continued group changed to Biannual in 2011	72 percent monthly 28 percent quarterly (Randomly assigned)	71 percent monthly (heavier users) 29 percent quarterly (lighter users)
Number of households			
Treatment: Continued	26,262	23,399	21,630
Treatment: Dropped	12,368	11,543	12,117
Control	33,524	43,945	49,290
Total	72,154	78,887	83,037

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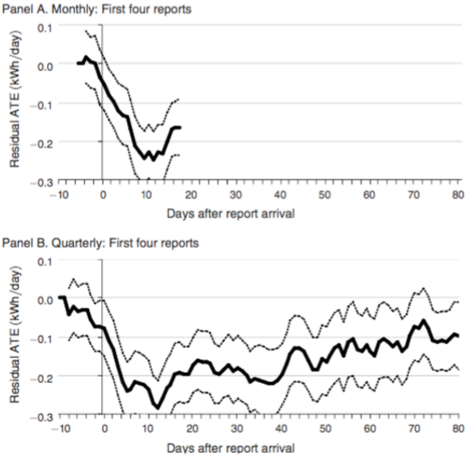
Main Results



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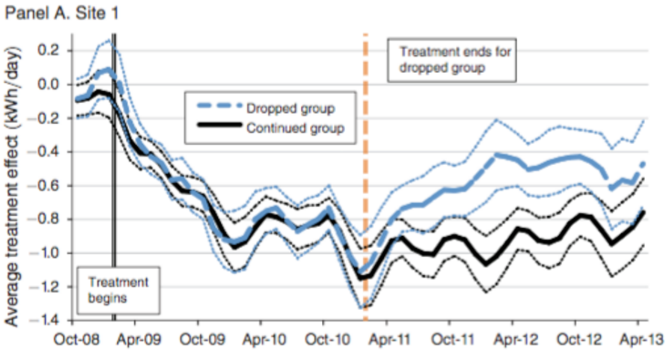
Main Results



Many recent developments in experiments!

- Importance of defaults (Fowlie et al, 2021)
- Load control (Shaffer el at, 2023 – working paper on water heaters)
- Load-shifting (Andersen et al, 2021 – in Denmark)
- Importance of salience/emergencies (Ito et al., 2018)
- Adverse selection and moral hazard in participation (Ito et al., 2021, 2023)

Real-time Pricing (RTP) and Time-of-Use (TOU): Evidence from Spain

Non-experimental evidence

- It is sometimes not feasible to run experiments at scale.
- One can exploit policy changes to examine the response of households, even if the environment is not perfectly controlled.
- Need to ensure that there are no “confounders” that could flaw the conclusions.

Non-experimental tools

- Event study: before and after
- Difference-in-difference: before and after with a control
- Instrumental variables: exogenous factors to pick up "unconfounded" variation

These tools can be enhanced with machine learning. The papers today use machine learning in their implementation (lasso + forests). Today, we will practice with a simpler version.

Today's examples

We will examine data from two research projects looking at the response of households to actual policies:

- Estimating the Elasticity to Real Time Pricing: Evidence from the Spanish Electricity Market,
- Measuring the Impact of Time-of-Use Pricing on Electricity Consumption: Evidence from Spain

Preview: Even if RTP is in theory better, TOU shifts consumption much more. **Code:** Simplified regression code will be provided in the website.

RTP: Fabra, Rapson, Reguant, and Wang (2021)

- Examine the implementation of mandatory RTP.
- Using detailed smart-meter data.
- But without "before-and-after" data.
- Identification comes from prices moving around.

AEA Papers and Proceedings 2021, 111: 425–429
https://doi.org/10.1257/pandp.20211007

Estimating the Elasticity to Real-Time Pricing: Evidence from the Spanish Electricity Market†

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

A central issue in renewable-dominated electricity systems is how to ensure that electricity demand is met at all times, even when renewable resources are scarce. The traditional solution in developed countries has been to overbuild capacity, but that is costly, as it requires investing in back-up plants that will rarely be used. In contrast, inducing consumers to alter their consumption patterns through price changes is increasingly viewed as an appealing way to help balance the system, reducing the need for excess production capacity and reducing production costs. Dynamic pricing incentives will become increasingly relevant as the share of intermittent renewable generation grows and batteries become highly valuable for shifting load.

Under ideal market conditions, the most effi- would harm poorly informed and/or highly price-inelastic consumers. As a consequence, there is a dearth of opportunities to study the effects of RTP in the field.

In this paper, we analyze the effects of the first large-scale deployment of RTP in the world, which occurred in Spain in October 2015.[1] Since then, Spanish households are defaulted into an opt-out RTP tariff that adjusts their retail electricity price hour by hour according to the outcome of the day-ahead wholesale electricity market. Effectively, this leads to a difference of 23 percent (on average) between the maximum and minimum prices within a day. The price schedule for the next day is published every day, and it is available online or via smartphone applications.

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Regulatory change: default RTP

- April 2014: In Spain, RTP becomes the **default option for all households** (below 10 kW).
- 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

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Data

- 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 and temperature data.

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

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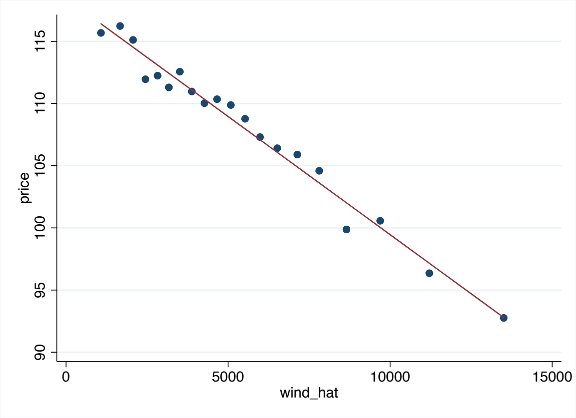
IV strategy

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



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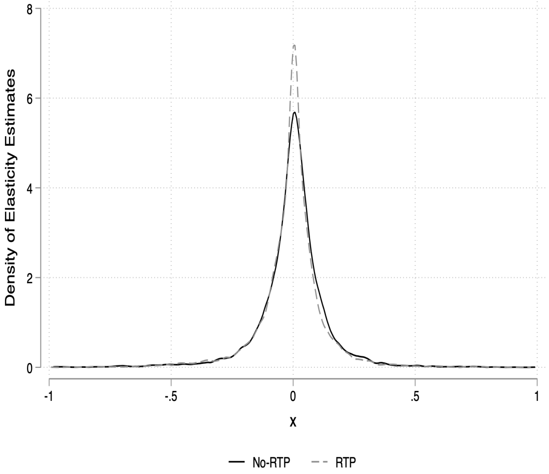
We find similar distributions of price elasticities



- Distribution centered around zero, median of no response.

Average elasticities by group are close to zero

- Not much of an effect from RTP.
- Additional difference zero.

- **Important:** Focused on very high frequency response, consumers do respond to permanent increases of electricity prices (e.g., energy crisis). See Deryugina et al, 2022.

	(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

TOU: Enrich, Li, Mizrahi, and Reguant (2023)

- Examine the implementation of mandatory TOU.
- Using aggregate hourly utility data for residential customers on default tariff
- With before-and-after and Portugal as a control.
- Identification comes from "diff-in-diff" or "triple-diff" (weekday/weekend).

Measuring the Impact of Time-of-Use Pricing on Electricity Consumption: Evidence from Spain

Jacint Enrich Ruoyi Li Alejandro Mizrahi Mar Reguant*

February 2023

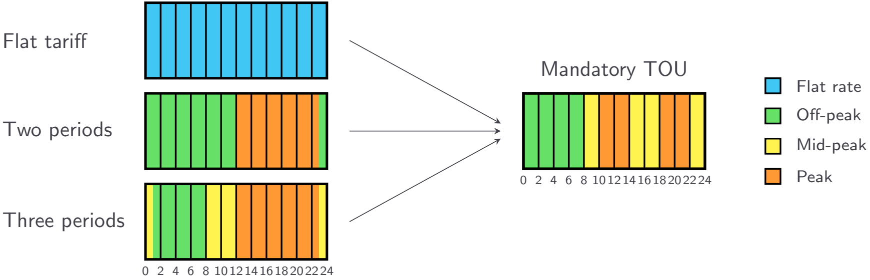
Abstract

We evaluate the effect of a time-of-use pricing program introduced in Spain on residential electricity consumption. Using a Difference-in-Difference approach, we find that households responded by reducing consumption during peak hours, although we do not find significant evidence of load-shifting. We then use machine learning for variable selection and show that it can help to obtain more precise estimates. We find that the program could have reduced consumption up to 12% during peak periods, partly offset by a 1.7% increase during off-peak hours. We also find evidence of habit formation during periods of uniform pricing, accompanied by an adaptation process that ends with a permanent change in consumption behavior. The results suggest that a predetermined pricing program can enhance consumer awareness and increase household price elasticity, thus making it an effective policy tool to reduce peak electricity demand and improve market efficiency.

Keywords: demand response, dynamic pricing, electricity.
JEL: H23, L94, Q41, Q48

Regulatory change: mandatory TOU

1. Energy cost (30%) ⇒ on RTP since 2015
2. Taxes (20%)
3. **System and Network charges (50%)⇒ changed June 2021**



Data

- **Electricity Demand** (hourly data):
  - Spain: Spanish System Operator (**REE**) - at the programming unit level
  - Portugal: Iberian Market Operator (**OMIE**)
- **Consumers** (monthly data):
  - Spain: Spanish National Markets and Competition Commission (**CNMC**)
  - Portugal: Bulletins of the Liberalized Electricity Market
- **Temperature** (hourly data): NASA MERRA-2 - 50X50km grid

$\Rightarrow$ **Period:** Jan 2018 - Sep 14th 2021, excluding 2020.

Machine Learning: Estimation

1. Estimate the following firm-hour specific regression using LASSO

$$Y_t = \gamma X_t + \epsilon_t$$

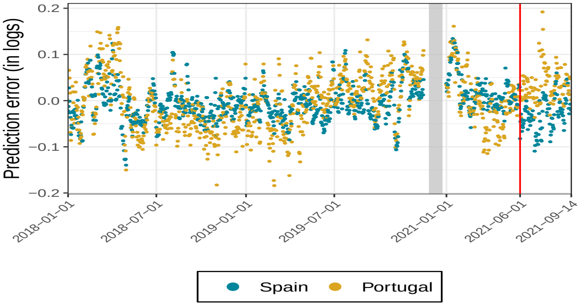
where

- Y_t is the consumption per capita of each regulated utility and Portugal
- X_t contains the following control variables: Month, weekend and national holiday dummies, Temperature (average, daily min and max) and all possible interactions
- Pre-treatment period: Jan 2018 - June 2021

Panel Fixed effects: Differences-in-Differences

2. Create In- and Out-of-sample predictions ($\hat{Y}$) and estimate the following fixed-effects regression

$$Y_{fht} - \hat{Y}_{fht} = \beta D_{fht} + \lambda P_{fht} + \delta_f \delta_h \delta_m + \delta_f \delta_y + \tau_{ms} + \epsilon_{fht}$$



Results: ML

Outcome Variable: Prediction error (in logs)			
	Baseline	Weekends	Weekday
Off-Peak	-0.016***	0.015*	0.017***
	(0.006)	(0.009)	(0.004)
Mid-Peak	-0.078***	-0.063**	-0.077***
	(0.017)	(0.023)	(0.015)
Peak	-0.126***	-0.079***	-0.124***
	(0.018)	(0.021)	(0.023)
Firm-Hour-Month	X	X	X
Firm-Year	X	X	X
Month of sample	X	X	X

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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.
  - Role of technology (smart thermostats), EVs, batteries.
- Need to analyze from a customer behavior point of view what the **"sweet spot"** could be.

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Next class

Demand II.

- What are the distributional impacts of the energy transition?
- How can we get at the heterogeneous impacts of the transition?

- **Presentations :)**

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