Empirical Methods for the Analysis of the Energy Transition: Day 5

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Today's outline

1) Distributional issues of the energy transition
   - Background
   - Review of two papers
2) Case study: RTP impacts in Spain

The challenges of the energy transition

- Need to reduce Green House Gas emissions (GHGs).
- Electricity sector (≈35-40% of CO2emissions) has been most active and has the greatest potential in making the transition.
- Ambition to move towards carbon-free electricity by 2035.

- **Limits to decarbonization**:
  - Renewables' intermittency might lead to a potential mismatch between supply and demand, increasing need for flexibility and batteries.
  - Extreme events with adverse outcomes for households intensify need for energy and put limits to decarbonization.
  - Uneven consequences of the energy transition and climate change create winners and losers, preventing policy progess.

The challenges of the energy transition

- The energy transition can have **substantial impacts on households** that can be highly heterogeneous.
- *Example*: Net-metering of solar can leave poorer households stranded without policy action.
- Uneven transition impacts combined with climate change impacts:
  - Households **most exposed to extreme events** tend to have the lowest income (poor building construction and insulation, heat islands).
  - The households are also least able to adapt and upgrade with **resilience** equipment (solar + backup battery, solar + EV as battery)

Impacts depend on market design and competition

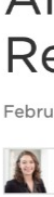
- Role of market design and competition is important:
  - What are the distributional implications of alternative market designs?
  - Are there provisions and safety nets in the face of more volatile prices?
  - Is there healthy competition that can mitigate some of these concerns?
  - How will retailers compete in the presence of these changes?
  - What should be done in the presence of rationing?

Distributional impacts impact the ability to complete the energy transition.

Equity impacts recently on the news

After Days Of Mass Outages, Some Texas Residents Now Face Huge Electricity Bills

February 21, 2021 · 12:01 PM ET



REBECCA HERSHER

Equity impacts can be devastating

WINTER STORM 2021

At least 111 people died in Texas during winter storm, most from hypothermia

The newly revised number is nearly twice the 57 that state health officials estimated last week and will likely continue to grow.

BY **SHAWN MULCAHY** MARCH 25, 2021 4 PM CENTRAL

COPY LINK REPUBLISH

Resilience preparedness not where most needed

Many open questions

- Huge need to think about **open topics concerning the energy transition** that seem highly suited for economists and that touch distributional issues:
  - Market design with renewables and climate policy.
  - Non-linear and dynamic pricing during energy transition.
  - Stranded assets and design of tariffs for fixed costs.
  - Competition with dynamic prices and heterogeneous consumers.
  - Solar panel and battery adoption.
  - Transportation electrification and combustion car phase out.
  - Heterogeneous impacts of reliability and resilience...

Many tools and data

Tools to examine distributional impacts:

- Theoretical models of pricing and regulation.
- Structural dynamic models.
- Demand models with rich unobserved heterogeneity.
- Equilibrium models of supply and demand with discrete choice adoption or continuous investments.
- Mathematical programming tools to solve for equilibrium.
- Plenty of high frequency data can be used to study these questions and build accurate models

Many challenges

There is large value in trying to think about how economics can contribute to **reducing the costs of large impacts of the energy transition and climate change**:

- Some of the future impacts will be necessarily not well identified.
- Need to build general equilibrium models of the energy transition with heterogeneous agents and calibrated responses.
- Need to use counterfactuals much more out of sample than we currently do.
- Prioritize realism over methodological choices.
- Large value to partnering with electrical engineers and climates scientists to understand the pressure of extreme temperatures or deployment of solar/EVs at a local level.

Examples of tools/topics in the literature

- Comparisons of **pricing impacts with micro data and aggregate income/demographic data** (Borenstein, 2012 – non-linear pricing; Leslie et al, 2021 – RTP pricing using substation data; Wang et al, 2021 – RTP pricing using household data).
- Quantification of impacts via detailed tax/purchase data (Davis & Borenstein, 2016 – US energy tax credits; Borenstein, 2017 – solar PV).
- Counterfactual equilibrium model of demand and supply based on householddata (Wolak, 2016 (water); Feger et al., 2021).
- Responses to uneven impacts of energy policies using survey data (Fabre and Douenne, 2022 - Yellow Vests) and electoral data (DeGroote, Gautier and Verboven, 2022 – solar PV).

Borenstein (2012)

The Redistributional Impact of Nonlinear Electricity Pricing†

By SEVERIN BORENSTEIN*

Electricity regulators often mandate increasing-block pricing (IBP)—i.e., marginal price increases with the customer's average daily usage—to protect low-income households from rising costs. IBP has no cost basis, raising a classic conflict between efficiency and distributional goals. Combining household-level utility billing data with census data on income, I find that IBP in California results in modest wealth redistribution, but creates substantial deadweight loss relative to the transfers. I also show that a common approach to studying income distribution effects by using median household income within census block groups may be misleading. (*JEL* D31, L11, L51, L94, L98, Q41, Q48)

Can non-linear pricing help?

- Non-linear pricing is quite common in utility tariff design.
- Main reason behind non-linear pricing:
  - Electricity prices are above marginal cost to pay for other costs.
  - These other costs often include at least part of fixed costs, e.g., transmission lines.
  - Instead of setting a fixed fee, many regulators set increasing non-linear prices.
    - Consumers with high levels of consumption end up paying substantially more at the margin, while consumers with low consumption get the first units at a low price.

Does it help the low income?

Non-linear pricing

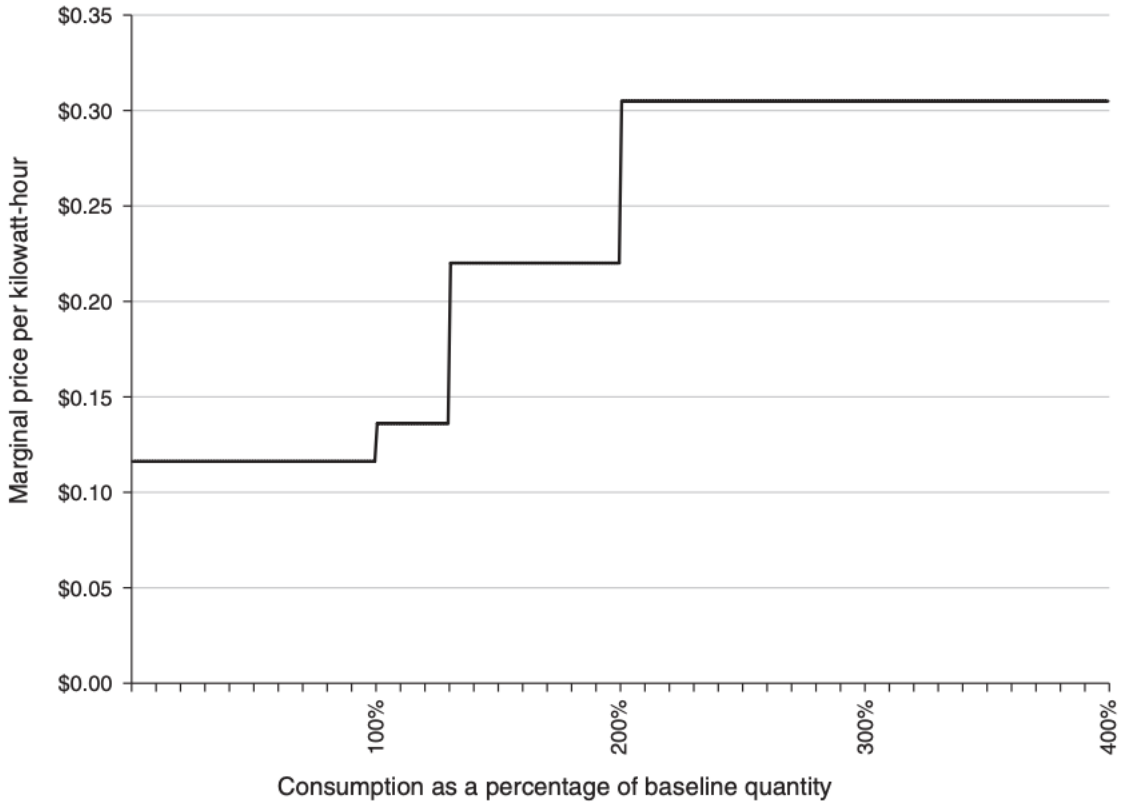


FIGURE 1. SCE'S STANDARD RETAIL ELECTRICITY TARIFF IN 2006

Basic patterns in the data

TABLE 1—DISTRIBUTION OF SCE RESIDENTIAL CUSTOMER CONSUMPTION ACROSS TARIFF TIERS IN 2006

	Residential usage (million-kWh)	Percentage of residential usage					CARE/Non-CARE shares	
		Tier 1	Tier 2	Tier 3	Tier 4	Tier 5	Percentage of usage	Percentage of customers
Non-CARE	23,046	52.9	10.7	16.5	10.9	9.0	79.3	74.8
CARE	6,016	66.0	10.7	13.5	6.7	3.1	20.7	25.2

	Percentage of customers on each tier for marginal consumption				
	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Non-CARE	32.4	14.2	25.0	17.2	11.3
CARE	45.4	16.7	22.7	10.9	4.3

Note: Reported results drop household accounts with consumption of less than 1 kWh/day.

What does the paper do?

Question: Is non-linear pricing progressive? To what extent?

Data: *Monthly* billing data for the three largest utilities in California (PG&E, SCE, SDG&E), social bonus status (CARE), median and mean income at the Census block group level (precise, small neighborhood area, but not individually).

Method: ecological methods to bound redistributive impacts under assumption of perfect sorting (higher consumption -> higher income) vs. no sorting vs. weighted based on survey data (most realistic).

Findings: Non-linear pricing is progressive, but it fails to perfectly target households.

Main comparison of impacts of non-linear price

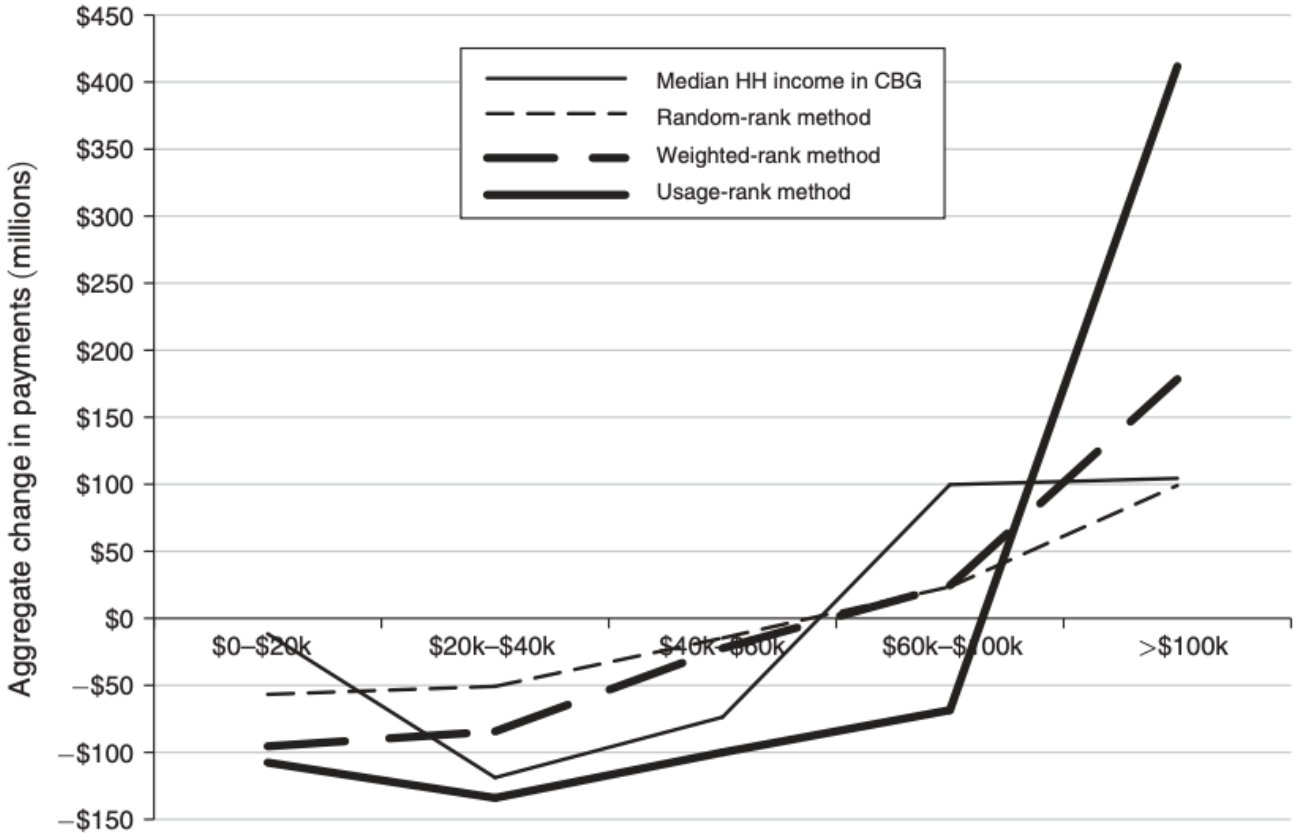


FIGURE 4. ALTERNATIVE ESTIMATES OF AGGREGATE CHANGE IN PAYMENTS BY INCOME BRACKET

Is social bonus better than non-linear targeting?

- Paper examines simulations with and without social bonus.
- As a challenge, social bonus is known to not be very well targeted in California, so it is not obvious which will work best.
- Under weighted method, bonus still contributes more to redistribution but non-linear pricing targets best the highest quintile.

TABLE 7—ESTIMATED AVERAGE ANNUAL BILLS WITH AND WITHOUT IBP AND CARE

	Average annualized bill				Bill change from No-CARE/flat		
	No-CARE		with CARE				
Income range	Flat tariff	Five-tier tariff	Flat tariff	Five-tier tariff	No-CARE Five-tier tariff	w/CARE Flat tariff	w/CARE Five-tier tariff
$0–$20k	$785	$653	$609	$546	−$132	−$176	−$239
$20k–$40k	$973	$879	$863	$804	−$94	−$111	−$170
$40k–$60k	$1,128	$1,098	$1,163	$1,115	−$29	$35	−$12
$60k–$100k	$1,234	$1,260	$1,337	$1,327	$26	$103	$93
>$100k	$1,646	$1,900	$1,790	$1,996	$253	$144	$350

Notes: All calculations using weighted-rank within-CBG allocation method. Excludes bills with daily consumption less than 1kWh/day. Includes all CARE and non-CARE customers.

Leslie, Pourkhanali, Roger (working paper, 2021)

Can real-time pricing be progressive? Identifying cross-subsidies under fixed-rate electricity tariffs

Gordon W. Leslie* Armin Pourkhanali Guillaume Roger†

October 26, 2021

Abstract

Wholesale electricity prices can rapidly change in real-time, yet households usually face fixed-price electricity tariffs. These tariffs create implicit cross-subsidies between households, determined by the timing of consumption. We map substation data on electricity use to demographic data to identify the household characteristics associated with this cross-subsidization. We find that households in areas with low house prices and high levels of renters and elderly residents are net funders of this cross-subsidy, and may be the greatest immediate beneficiaries if real-time retail tariffs are made available. Further, cross-subsidy magnitudes are exacerbated by the wholesale price impacts from increasing solar generator penetration.

JEL classification: D12, D18, H23, L94, Q41
Keywords: Real-time pricing, Cross-subsidies, Tariff design, Clean energy transition, Energy demand.

What does the paper do?

Question: Is real-time pricing progressive? To what extent?

Data: half-hourly substation consumption data in Victoria (AUS) matched to geographical demographic data including income and other covariates, data on number of businesses and households, weather data.

Method: Regression that separates business vs. household consumption, then focus on household consumption to look at redistribution across substations.

Findings: Real-time pricing favors low-income consumers on average.

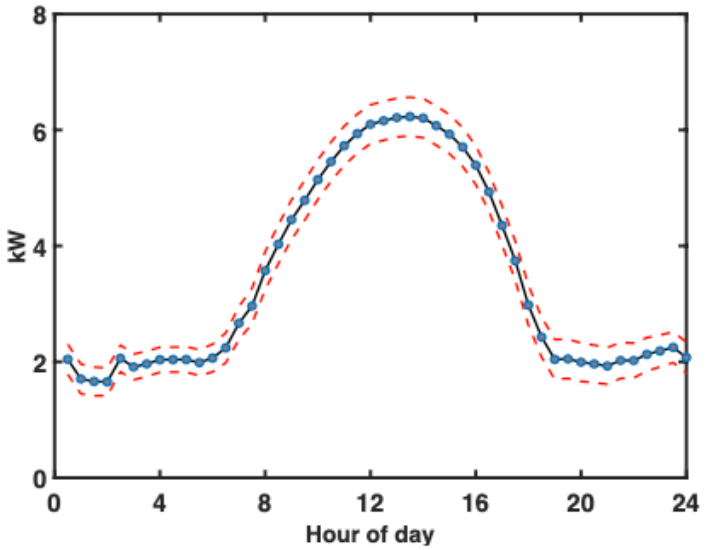
Regression approach

- Use regression with number of households and businesses, allowing hourly consumption to depend on neighborhood characteristics.
- Each substation ranked into terciles (high, medium, low) for 12 measures
  - **Demographics**: prop. of people over age 65; av. h'hold size, prop. born o'seas; prop. work from home; unemployment; av. income; prop. Uni.
  - **Housing**: prop. rental; median house price; residential density; prop. rooftop solar.
  - **Climate**: cooling degree days

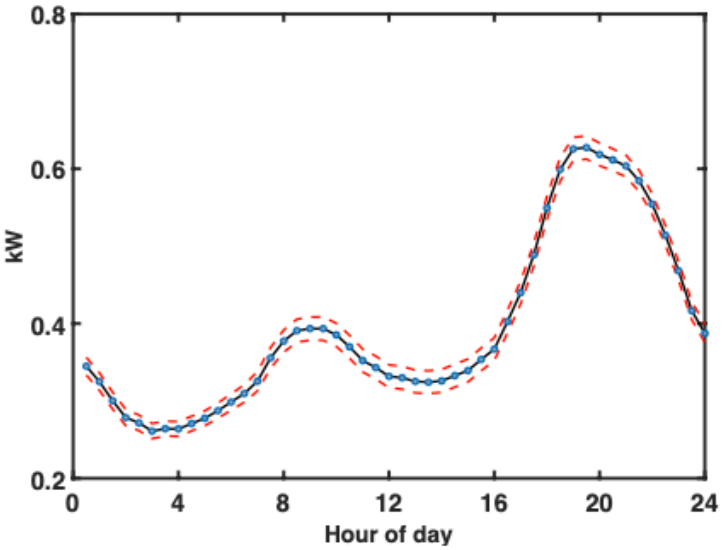
- Focus on predicted household consumption β_h interacted with characteristics Z_s.

$$Q_{s,t} = \alpha_h + \beta_h \cdot \underbrace{Z_s}_{\text{Char's}} \cdot |I_s| + \gamma_h \cdot |J_s| + \epsilon_{s,t}$$

Method seems to extract meaningful signal



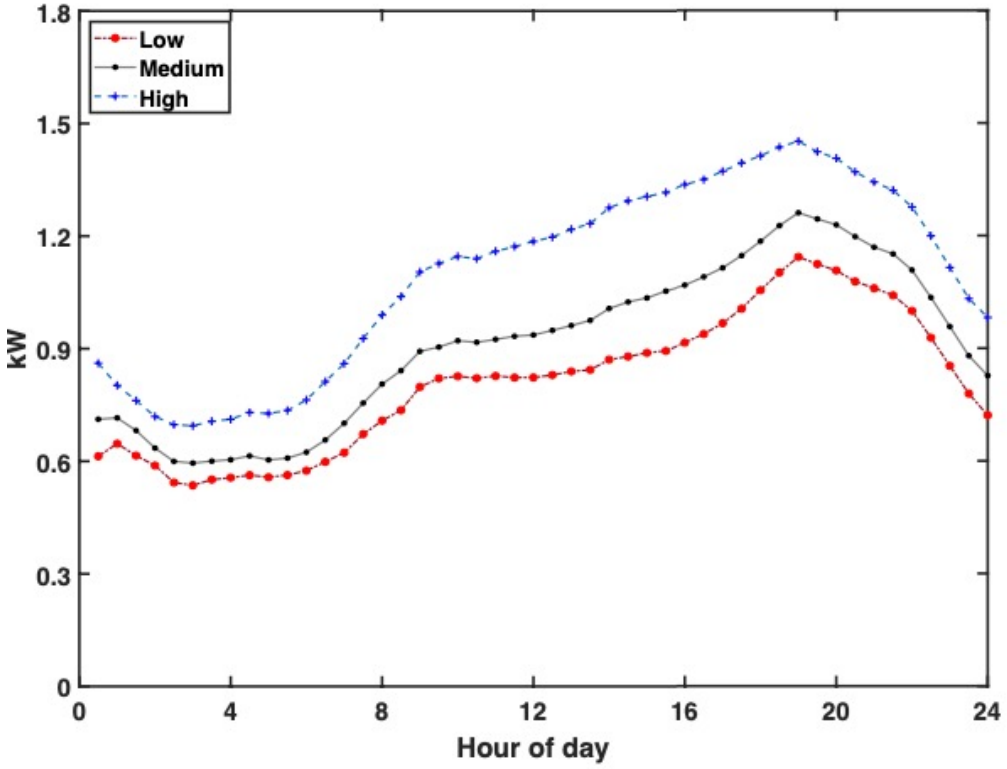
Business profiles



Household profiles

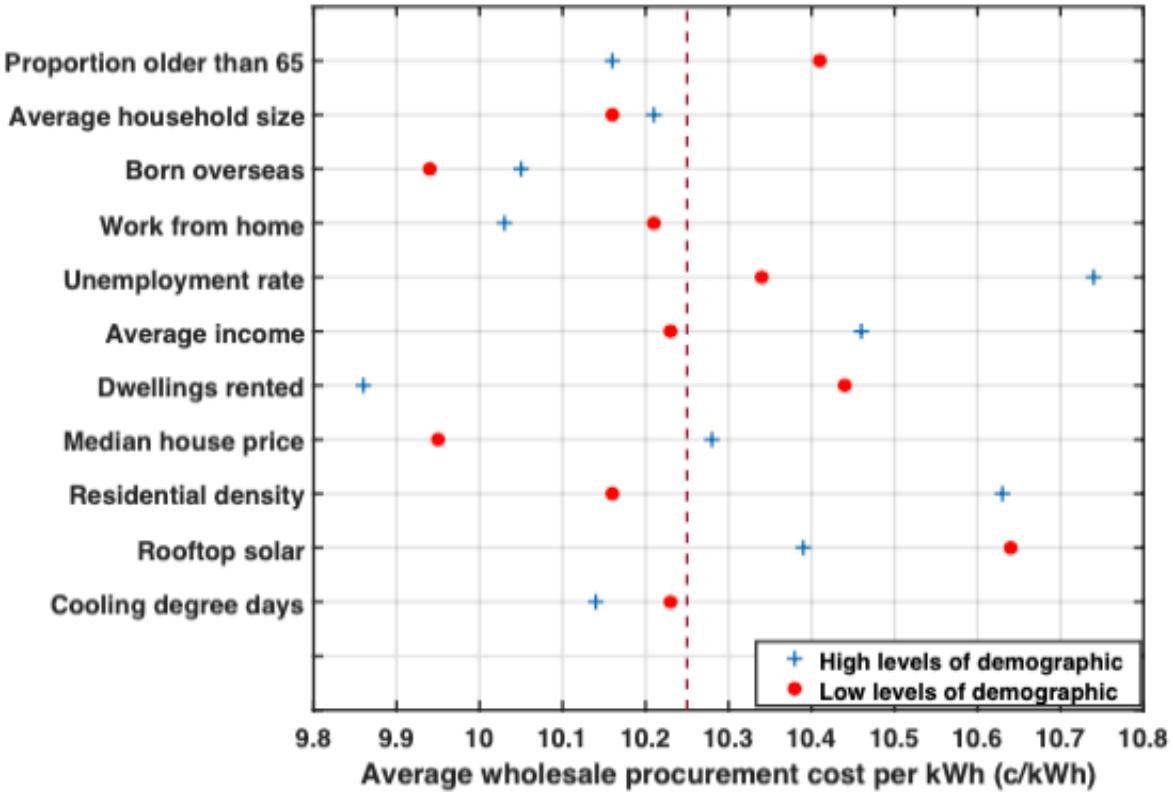
And it is relatively simple!

Method seems to extract meaningful signal



(e) Cooling degree days

Results for cross-subsidization



Average cost taking with RTP by demographics

Summary of findings

- Relationship between costs per MWh under RTP (compared to everyone the same) suggest that some sensitive demographic categories benefit under RTP.
- RTP is not necessarily regressive, although heterogeneity in impacts is substantial even with aggregate substation data.

- Some open questions:
  - Victoria has a very large share of rooftop adoption, how does interact with RTP when looking at distributional impacts?
  - How does it depend on solar pricing design, e.g., net-metering vs. other alternatives?

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Distributional impacts in our case studies

- **[Day 2]** The Efficiency and Sectoral Distributional Implications of Large-Scale Renewable Policies, JAERE, 2019.
- **[Day1]** Measuring the Impact of Wind Power in the Spanish Electricity Market, w/ Claire Petersen and Lola Segura.
- **[Today]** The Distributional Impacts of Real-Time Pricing, w/ Jingyuan Wang, Natalia Fabra, and Michael Cahana.

Paper #1: Industrial vs. residential sectors

- **Question**: Examine current practice of charging renewable costs mostly to residential sector.
- **Data**: California market data to calibrate a stylized model of an electricity market with 3 types of end users (I, C, R).
- **Methods**: Ramsey pricing theory with externalities, computational tools for quant assessment.
- **Finding**: Charging residential HH cannot be justified by Ramsey pricing unless industrial sector leaks.

Paper #2: Producers vs. consumers sectors

- **Question**: Examine the welfare implications of wind subsidies at the margin (vs. lump sum).
- **Data**: 10-year time series from the Spanish electricity market.
- **Methods**: Reduced form analysis of the quantile impact of wind generation, event study to examine regulation change.
- **Finding**: Moving from PTC to ITC had large distributional implications, making consumers worse off.

Paper #3: High- vs. low-income consumers

- **Question**: Examine heterogeneous impacts from defaulting residential consumers into dynamic real-time pricing (RTP).
- **Data**: Detailed smart meter data from millions of households in Spain.
- **Methods**: k-means clustering based on smart meter data combined with distributional aggregate moments of income distribution.
- **Finding**: Move towards RTP was mildly progressive, caveats on likely different impacts going forward.

Wang, Reguant, Fabra, and Cahana (2021)

Slides

Thank you!

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