Smart Rationing

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Rationing

- I will talk about early work on **rationing** in the presence of energy scarcity.
- Growing concerns about high natural gas prices and the possibility of shortages in Europe.
- Several leaders announced the possibility of consumer-level planned blackouts (e.g., Austria, France).
- While consumer blackouts are *quite unlikely* in Europe (especially planned blackouts), it is important to study its design as it might be a more likely event in the future due to climate change.
  - System failure due to shocks: California, Texas
  - Demand spikes during adverse conditions

Persistent blackout conditions are costly

NEWS // HOUSTON & TEXAS

Texas energy demand may exhaust supply this summer, ERCOT warns

Texas' energy grid operator warned that extreme scenarios may lead to rolling blackouts this summer.

Michael Murney, Chron
May 5, 2023

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

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Individual/public investments can help, highly unequal

- High-income households can avoid blackouts with solar + battery systems that are oversized absent blackout concerns.
- With the raise of solar + batteries (microgrids), blackouts, one can also build electrical shelters.
- All these solutions will ease the burden to some households and neighborhoods,impact of a rolling blackouts fall on HHs that cannot afford resilience preparedness.

How to improve blackout policies?

Traditional "rolling" blackouts can have very large costs

- Following Joskow and Tirole (2011), net surplus is defined as:

$$W_t(p, \alpha_t) \equiv S_t(p, \alpha_t) - pD_t(p, \alpha_t).$$

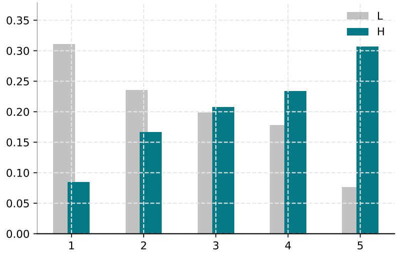
- α_t reflects the degree of rationing at a given moment in time.
- With random rationing, only a fraction α_t gets the net surplus, the rest remains in the dark with utility given by some lower bound without electricity:

$$W_t^R(p, \alpha_t) = \alpha_t W_t(p, 0) + (1 - \alpha_t) W_t(p, 1).$$

- Notice that α_t might be small, but costs to selected consumers can be large if the blackout is severe (e.g., Texas).

Maximum power limits offer a better solution

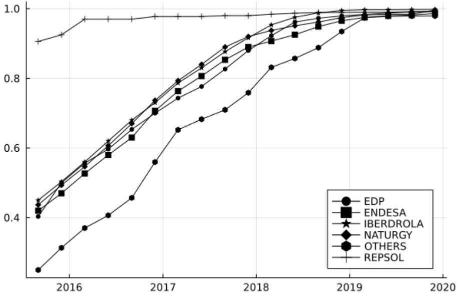
- Consumers in many countries can contract their maximum power level at any instantaneous point for the duration of a certain period of time (limited changes).
- This is the so-called "Potencia contratada."
  - Used for cost-allocation purposes: consumers with high potencia contribute more to fixed system costs, highly correlated with income.
- If a user goes over their contracted power, the circuit breaker trips.
- The user has to disconnect enough appliance to be back in balance (aka, below the limit).



From "The Distributional Impacts of Real-Time Pricing."

From smart meters to smart rationing

- Smart meters are now commonplace in many electricity markets.
- Its benefits are multiple: potential for dynamic pricing, reduction in distribution losses, better solar pricing, etc.
- Smart meters can also contribute to improved rationing via maximum power limits.
- Traditionally, this maximum limit used to be a "bug" in the device and had to be adjusted manually.
- Nowadays, it can be adapted digitally.



From "Smart Meters and Retail Competition: Trends and Challenges."

Smart rationing as a partial blackout

- In the traditional blackout setting, a customer was either disconnected or not.
- Smart meters allow to partially limit the available power to a user.
- In notation,

$$W_t(p, \omega),$$

  where ω is some form of flexible rationing rule that reduces the consumption of a household.
- Notice that ω trivially includes the simple blackout rationing.

Benefits of smart rationing

- Under very reasonable assumptions, it is trivial to show that a form of "smart rationing" should be preferable to full blackouts for a small subset of the population.
- We define the equivalent smart rationing rule for a certain amount of rationing:

$$W_t^R(p, \alpha_t) = \alpha_t W_t(p, 0) + (1 - \alpha_t) W_t(p, 1)$$

vs.

$$W_t^{SR}(p, \alpha_t) \equiv max_\omega W_t(p, \omega) \ \text{ s.t. } \ D(p, \omega) = \alpha_t D(p).$$

- Notice that ω trivially includes the simple blackout rationing.
- Also, intuitively, having some power should be much preferable than none at all, so potentially $W_t^{SR}(p, \alpha_t) >> W_t^R(p, \alpha_t)$.

When can this be useful

- This is not useful for blackouts that happen unexpectedly or need immediate action due to communications protocol with smart meters.
- This is also less useful in situations where network topology is very important (e.g., wildfires).

- Useful for situations like European crisis, Texas, California (non-fire): expected and persistent.
- In some sense, similar to water scarcity problems as a way to reduce demand once other channels have failed (or might not be feasible).

Many open questions to make this an implementable mechanism

- What are the smart rationing protocols that ensure $\alpha_t D(p) = D(p, \omega)$?
- How does it depend on the communication protocol, e.g., if only a portion $\gamma_t \geq \alpha_t$ can be modified in time? What if only a region at a time can be reached?
- What are the impacts of smart rationing on households of different income levels?
- Should rationing depend on heating mode and other relevant aspects of electricity use?
- Should some of this be contractible? Why or why not?

Mostly in progress!

Data

- Data as in Fabra et al (2020, 2023).
- We obtained data for over 4M smart meters from one large Spanish utility (Naturgy).
- For each meter (January 2016-July 2017), we have:
  - hourly electricity consumption
  - plan characteristics (pricing, contracted power)
  - postal code
- We link the postal code with detailed Census data on income.

Simulations

- We have started to run some simulations with our smart meter data to understand the equivalent-blackout policies under different assumptions of rationing.
- As of now, we assume random rationing, which can be complete (blackout) or partial (reduced maximum power).
- We also consider geographically-correlated blackouts.

Simulation details

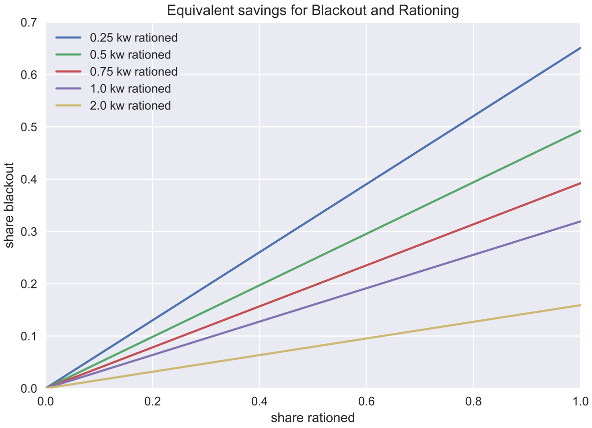
- We have started to run some simulations with our smart meter data.
- As of now, we assume *random* rationing throughout, which can be complete (blackout) or partial (reduced maximum power).
- For each household i, with our implementation of "smart" rationing, demand equals to:

$$D_{it}(p, \kappa) = \min\{D_{it}(p), \kappa\}.$$

- κ is the limit per household (in kW).
- We consider $\kappa = \{0.0, 0.5, 0.75, 1.0, 2.0\}$.
- We can find $\gamma(\kappa)$ such that rationing is equivalent to a blackout of probability α_t.

Equivalence frontier

- All lines are below the 45-degree line: partial random rationing necessarily need to impact more households.
- Due to random assignment, also by construction linear (in expectation and precise due to LLN).
- Example: to equal a 10% full blackout, 20% of households need to be rationed at 0.5 kW.



Some notes

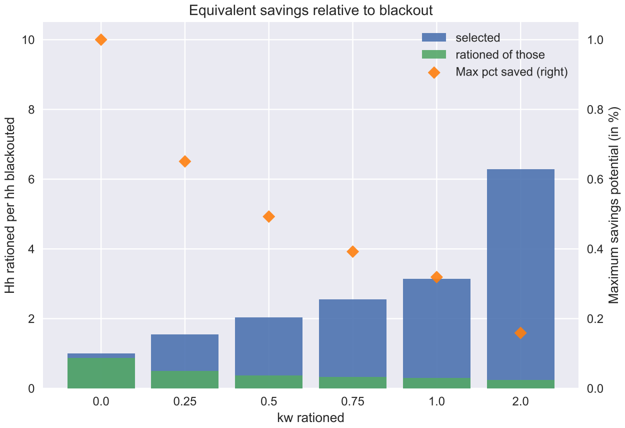
- Under partial rationing, not all households are partially rationed.
- We separate **effectively rationed** vs. **selected but unrationed** households.
- This is a useful concept to think about welfare and incidence.

- Under random rationing, conditional on a given κ, the *share* of effectively rationed and selected but unrationed remains constant along γ.

- Also important to notice that there are natural limits to partial rationing: a 100% full blackout cannot be replicated by any partial rationing policy.

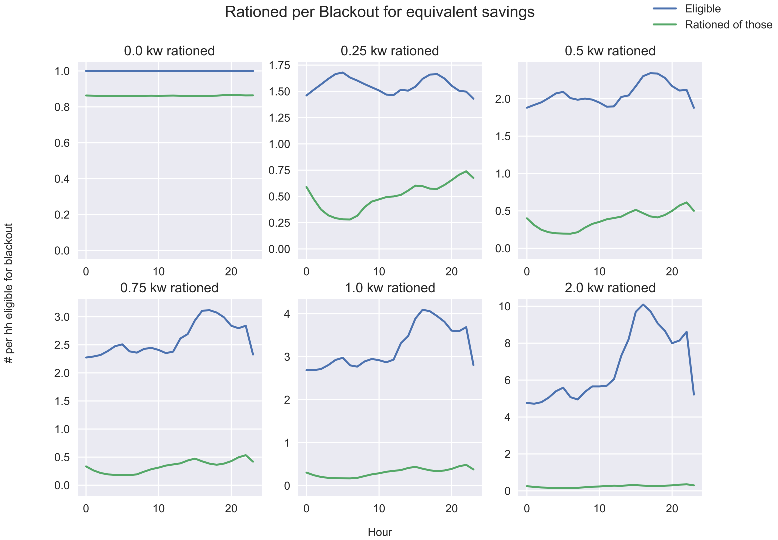
Impacted consumers and limits to partial rationing

- The more generous the partial rationing, the more people need to be selected.
- However, rationing effectively affects fewer and fewer people.
- Note: this is an empirical question, driven by the shape of consumption.
- Generalized partial blackouts can mimic large blackouts.



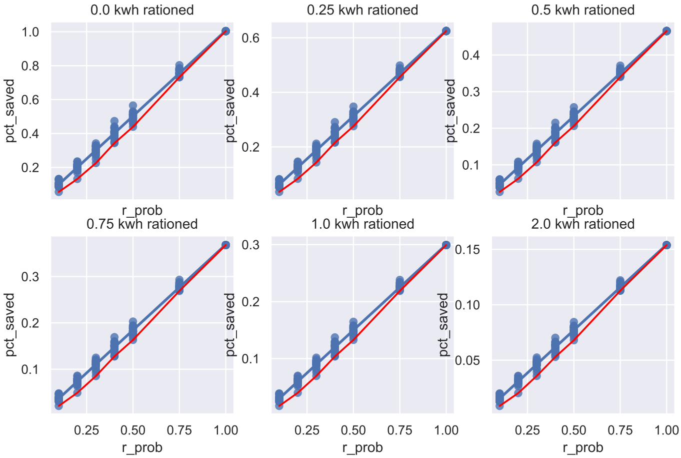
Impact of the rule depends on demand patterns

- Rationing policies have less impact at night.
- More homogeneous consumption across households during the night, impacts number of selected households and actually rationed households.



Geographical aggregation matters

- If rationing has to be done at the zip-code level, there is less amount of randomization.
- Lower envelope to ensure α-equivalent blackout is achieved becomes more aggressive.
- Particularly relevant for small blackouts where only one or two zip-codes need to be rationed.



Next steps

- Incorporate appliance ownership and household-level income predictions from Cahana et al. (2022).
- Explore limiting factors to communication protocol: zip-level correlated messaging instead of fully random.
- Explore notions of welfare under rationing, budget constraints, and extreme events.

Thank you.

Questions? Comments?

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