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Electricity Transmission Infrastructure and Decarbonization

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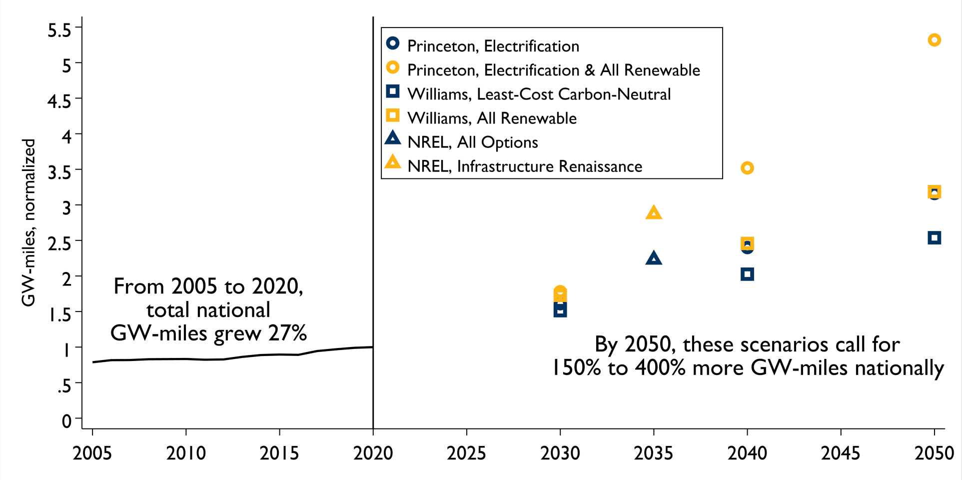
- Lowers aggregate production costs and brings gains from trade.
- Especially relevant in electricity markets: convex supply curves, inelastic demand, lack of widespread storage.
- Especially relevant in a green transition (Joskow 2021, NAS 2021, Davis et al. 2023).

Decarbonization scenarios call for much more transmission



Source: Davis, Hausman, and Rose

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Decarbonization scenarios call for much more transmission

- Transmission grid was built for fossil plants to be fairly close to demand centers.
- Renewables are located in different parts of the country.
- Renewable generation gets curtailed even when more expensive fossil plants are running in other regions.
- Weakening incentives for new renewable investment (Gonzales et al. 2023).

In this paper...

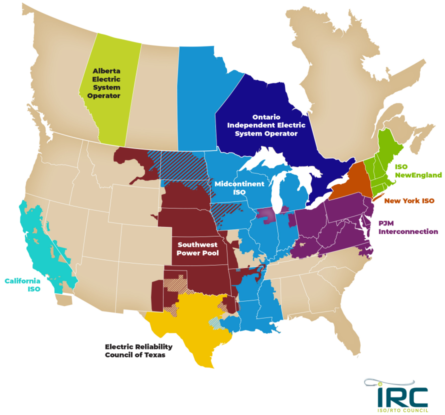
- Focusing on two major markets: MISO and SPP (renewable rich, with major demand centers),
- I construct supply curves under two primary counterfactuals:
  - Under full integration, zero curtailments.
  - Given today's transmission grid, and given current curtailment levels.
- I next show that generators are dispatched as if transmission constraints are binding.
- Then I calculate net revenue changes at generation-owning companies.

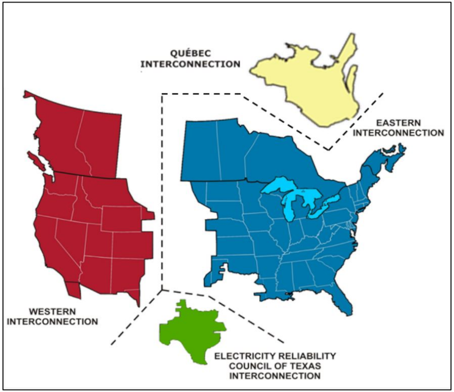
I find that...

- Allocative inefficiencies were low in the recent past ($300-400 million per year over 2016-2020),
- But rose to $2 billion in 2022.
- Losses at some individual companies are large: for instance, totaling $1.6 billion in 2022 for four firms.
  - And renewables advocates have claimed two of these firms have been blocking new lines.

Background

- The Midwest has two markets (SPP and MISO, two Independent System Operators),
- But the grid is physically connected across those markets.





Data

- Hourly generation at each power plant
- Fuel and technology type
- Location
- Ownership (company name and IOU vs. IPP)
- Aggregate hourly renewable and nuclear generation

Research question 1: How much would **allocative efficiency** change if transmission constraints were relaxed?

- Compare least-cost dispatch with and without transmission constraints.
- Need to build counterfactual supply curves: who will be dispatched according to marginal cost ranking?

Counterfactual supply curves

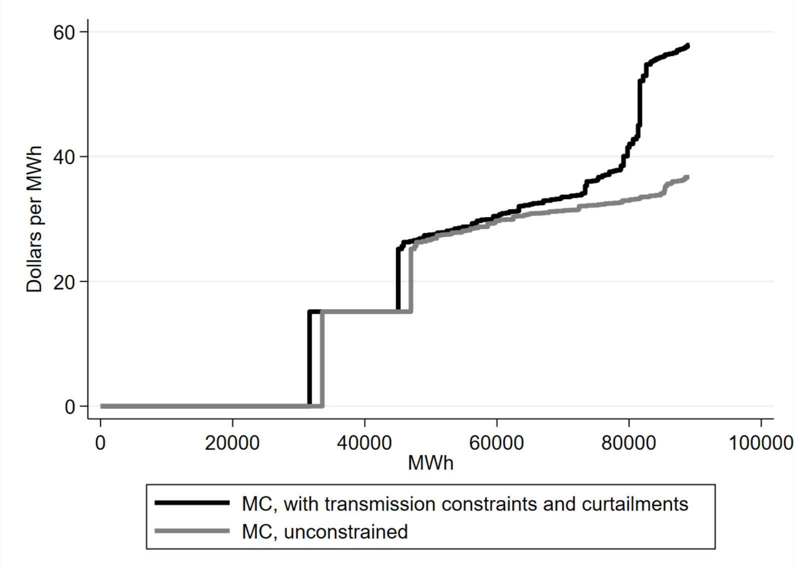
- Rank units according to constructed marginal cost:

$$mc_{i,t} = fp_t \cdot hr_i + om_{i,t} + ec_{i,t}$$

  Marginal cost depends on fuel prices, heat rates, operating & maintenance costs, and environmental compliance.

- Borenstein, Bushnell and Wolak (2002); Deetjen and Azevedo (2019); Mills et al. (2021); Cicala (2022); etc.

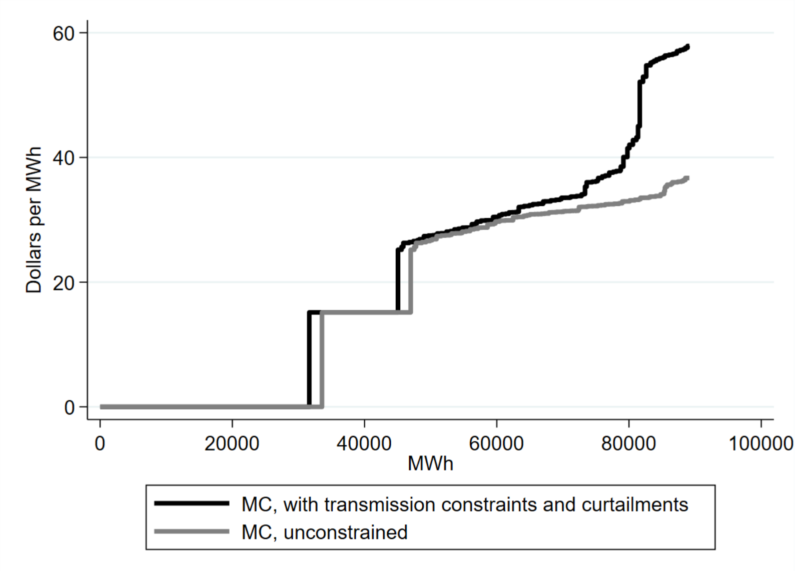
Supply curve at a representative hour in 2022



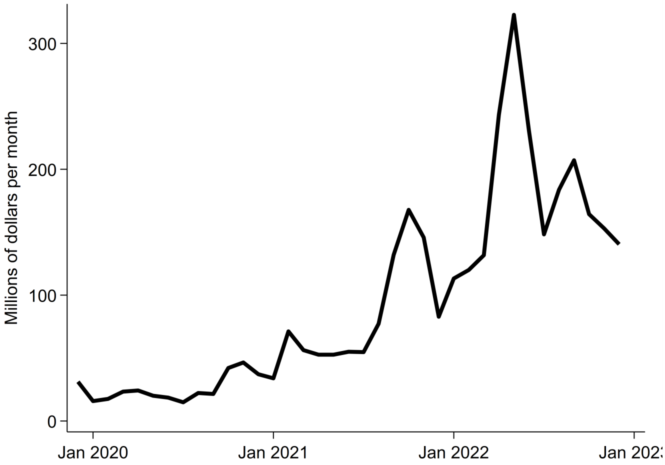
Counterfactual supply curves with transmission constraints and curtailment

- Assign each power plant to a NERC sub-region.
- Infer transmission constraints across sub-regions from observed generation.
- Re-run least-cost dispatch, constraining region-wide generation to what is observed in the data (hourly).
- Curtailments: reported by ISO.

Supply curve at a representative hour in 2022



Doing this for every hour yields a time series of the wedge



Annual allocative inefficiencies

Annual cost, billion dollars	2016-2020	2021	2022
Total	0.32 to 0.43	0.98	2.16
Across-ISO constraints	0.03	0.10	0.21
Within-ISO constraints	0.25	0.57	1.31
Curtailments	0.03 to 0.14	0.31	0.64
Within-SPP constraints	0.08	0.12	0.19
Within-MISO constraints	0.18	0.45	1.12

Visualizing these transmission constraints

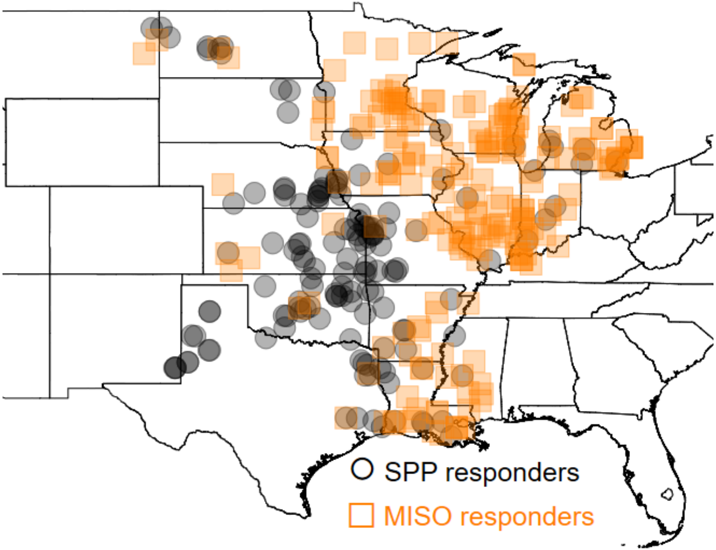
- Empirical strategy: to which load (demand) is generator dispatch most likely to respond?
- If the grid were physically unconstrained, generators would respond equally to a demand shock in any location.
- Identifying assumption: demand shocks are exogenous.

"Horse race" regressions

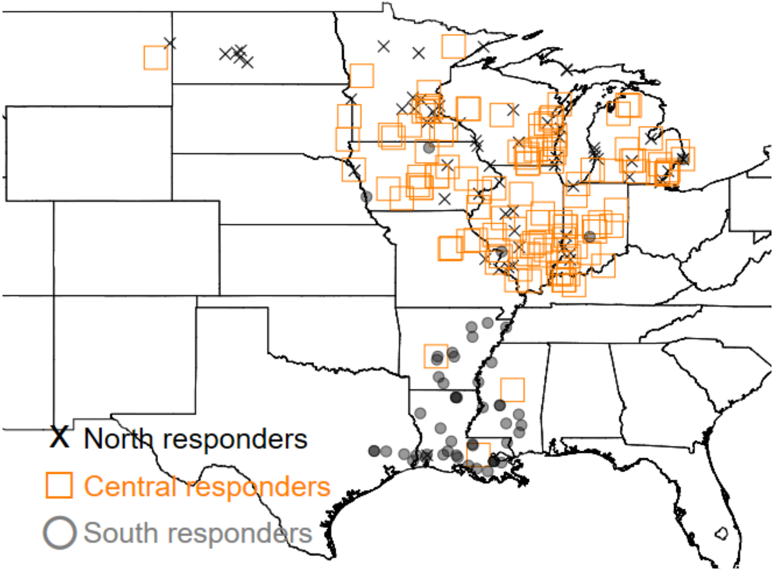
$$g_{i,t} = \beta_1 d_{SPP,t} + \beta_2 d_{MISO,t} + \beta_3 d_{EI,t} + X_t \Theta + \varepsilon_{i,t}$$

- Generation at each power plant in each hour depends on: demand in SPP, demand in MISO, and demand in the rest of the Eastern Interconnection.
- Controls include: fuel prices, ambient temperature in each state, a time trend, month-of-year effects, day-of-week effects, and hour-of-day effects.

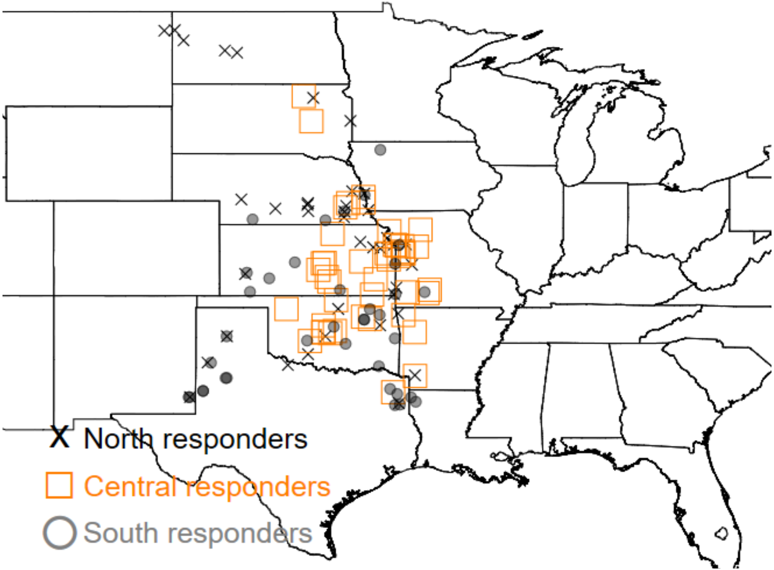
Own ISO typically has the larger coefficient...



Within MISO, own region has the larger coefficient



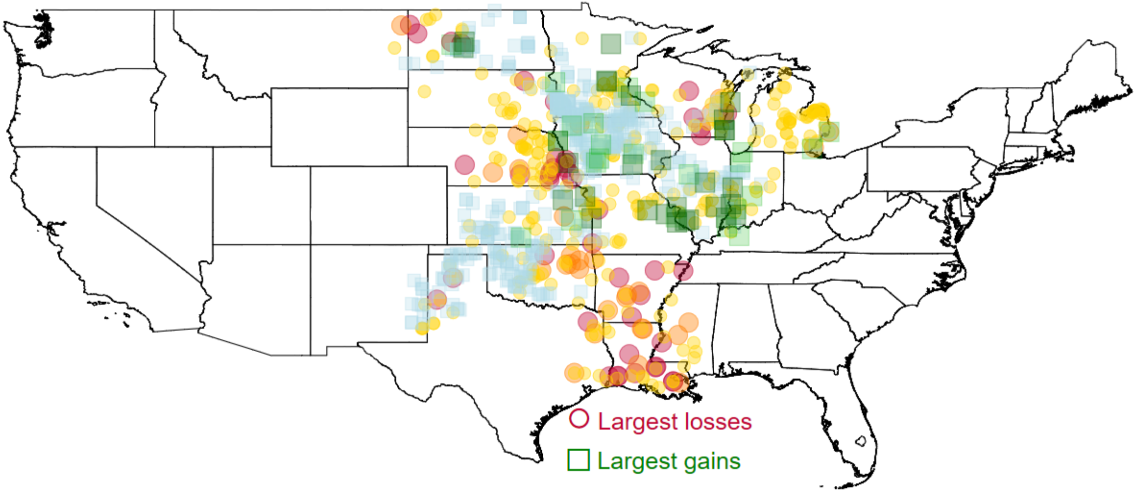
Within SPP, own region appears to matter less



Research question 2: Which generators would **win** and which would **lose** if the constraints were relaxed?

- Why this is important:
- Transmission planning is largely a consensus-based process.
- And transmission construction will entail winners and losers:
  - Revenues will go down in load pockets;
  - Revenues will go up in windy areas.
- What are the magnitudes of these effects? Does it help explain some of why transmission is hard to build?

Winners and losers are located in different places



Case study: MISO South

- 2012: Entergy joins MISO following DOJ investigation into anti-competitive use of transmission
- 2020-2023:
  - Watchdog groups circulate reports that Entergy tries to slow down the transmission planning process in MISO
  - Entergy sends consultant to MISO meetings "under the guise of a 'MISO south customer' "
  - Entergy builds two new fossil plants in places where MISO would otherwise have built new tx lines.
- Caveat: many of the most vocal critics of Entergy have ties to renewable energy.

Wrapping up: additional issues in transmission

- No centralized regulatory process
- Siting and permitting challenges; NIMBYism
- Approval required from federal, state, and local authorities
- Disagreements about cost allocation
- Interconnection costs; local grid upgrades
- Storage as a substitute?
- Dynamic pricing as a substitute?

Wrapping up: the political economy of climate change

“Climate change and climate policy are altering the value of assets, from real estate and power plants to the labor of fossil fuel workers. This process generates increasingly contentious political battles over which assets, professions, and communities will retain value or even survive at all” (Colgan, Green, and Hale 2021)

Thank you!