Modeling Uncertainty in Climate Policy

Bushnell and Smith

An Application to the US IRA

TPUG-AEA 2025

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Overview

Tackles uncertainty in climate policy

- ~~Climate Policy~~ Energy systems models
  - Can't study climate policy without an energy system model
  - Grid is 33% of US emissions
  - Vastly more if transport is largely electrified
  - Useful for understanding grid evolution, not just for climate policy

Big contribution here

- Data uncertainty on the assumptions about future inputs
  - Future electricity demand
  - Future NG prices
  - Future interest rates
  - **joint** distributions
- Data uncertainty is $Y = f(\tilde{X})$
  - Model uncertainty $Y = \tilde{f}\,(X)$
  - We can't know model inputs X_t perfectly, so draw from distribution and run simulation
  - Joint distribution of many time series'
- Allows for strikingly many more inputs to be forecast
  - Regional detail (!!)
  - Transmission constraints considered

Overview

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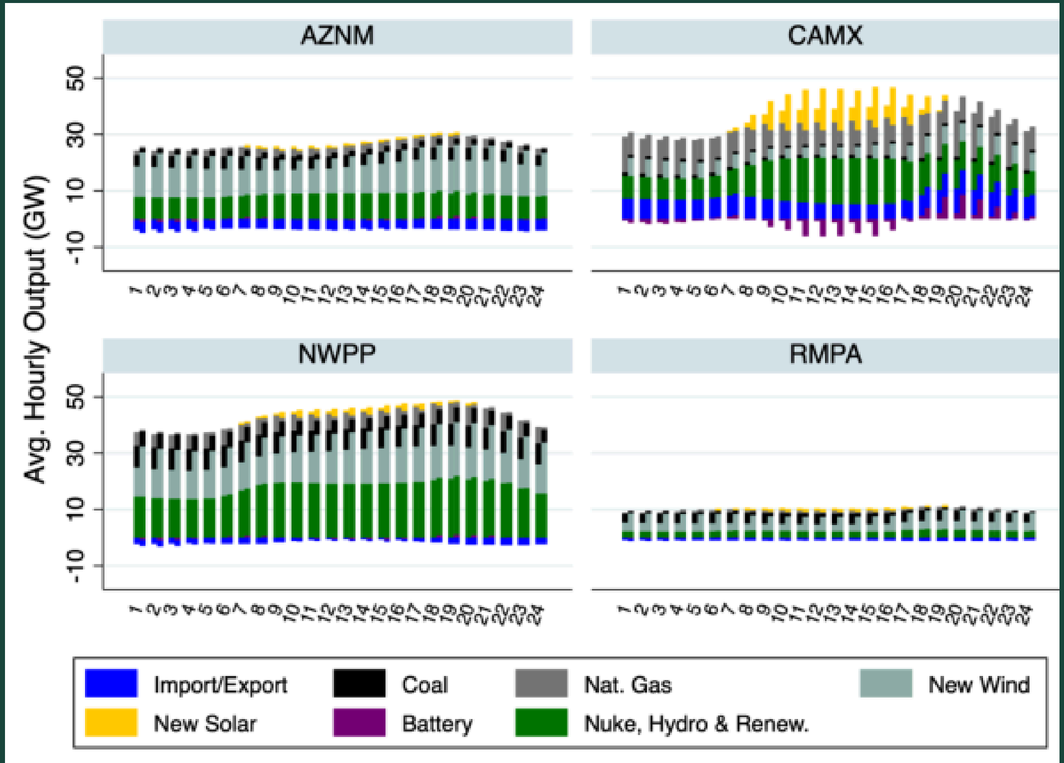
Dynamic Factor Model

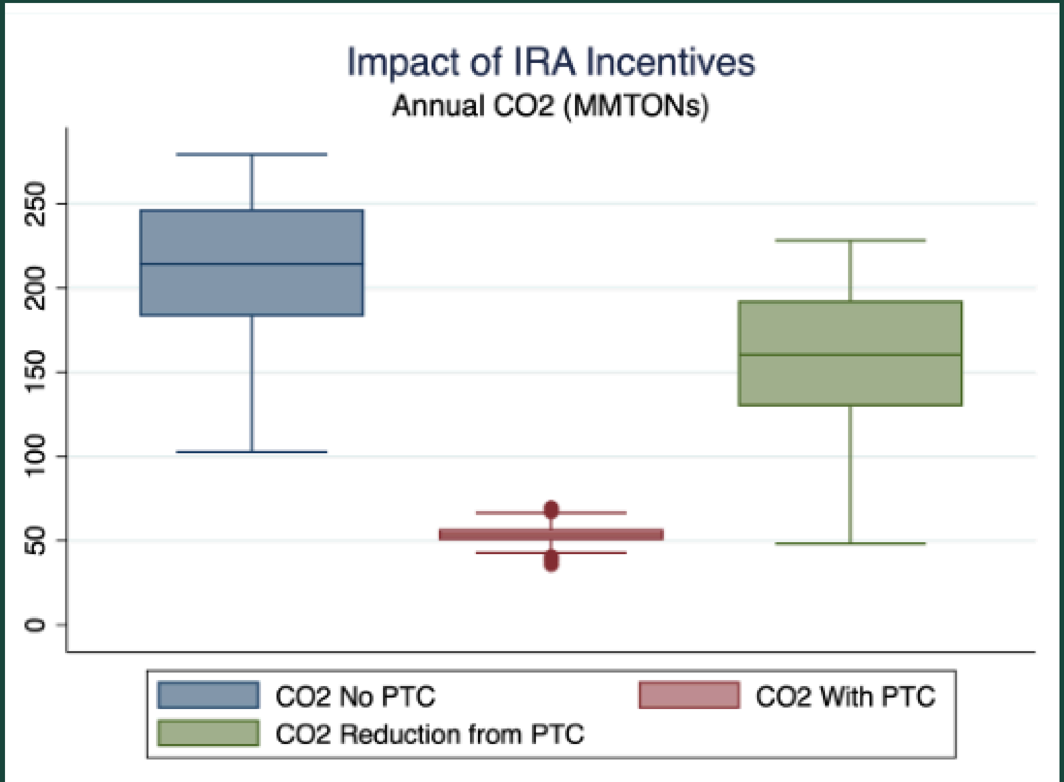
- Many variables $\longrightarrow$ PCA $\longrightarrow$ small number of factors
  - E.g. each region is projected back from factor
- Small number of factors (9) is feasible for VAR
- Draw factor from VAR results, draw input X_t from factor results,
  - Optimize operation and optimize investment for 2030

Data-driven parsimony

- Elegant in construction

Results


AZNM
CAMX
NWPP
RMPA
Avg. Hourly Output (GW)
-10
10
30
50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Import/Export
Coal
Nat. Gas
New Wind
New Solar
Battery
Nuke, Hydro & Renew.


Impact of IRA Incentives
Annual CO2 (MMTONs)
0
50
100
150
200
250
CO2 No PTC
CO2 With PTC
CO2 Reduction from PTC

Comment 1

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Illustrate correlation between key inputs

- Think: NG price and interest rate
  - Macroeconomic conditions
- Does the DFM predict correlations similar to observed?

How often do grid simulation-based policy analyses use two highly correlated inputs in separate scenarios?

- Table of scenarios from 5-6 published IRA papers
- Show any cases of scenarios that assume correlations (e.g. "high NG/high interest rate scenario")
- 🚌

Comment 2

VAR on factors assumes stable relationship

- But does IRA potentially affect those relationships?
- Major policy, major changes $\rightarrow$ factors

For instance

- PTC may drive lower battery costs $\rightarrow$ co-adoption of battery + solar
  - $\Rightarrow$ Peak electricity demand relation to electricity sales in a state may be affected
- Other IRA programs interact
  - Temperature and electricity sales relationship may be affected by e.g. heat pumps and EVs

Even factor trends may be affected

- Forecast energy demand factor trend estimated pre-2019 -- EVs?
- 2018 CEC forecast for 2030 "low demand" scenario was 326 TWh
  - DFM predicts 275-355 TWh

Overnight Capital Costs of new generation

- Annualized cost per unit capacity $F_j = OCC \cdot \frac{r(1+r)^n}{(1+r)^n - 1}$
- r forecast in VAR
- Conservative estimates on OCC declines by 2030

Uncertainty on OCC

- (admittedly ad hoc) distribution on OCC for 2030

"Dynamic" OCC

- Scale effects, endogenous technlogical innovation (e.g. Gerarden (2023))

Smaller comments

I: 2 characteristic days

- 1 peak day, 1 off-peak day, weighted $\frac{1}{90}, \frac{89}{90}$
- 2 points does not capture "curvature" of dispatch and cost
- 3 points? Bottom 50%, next 24%, then top 1%?

II: Transmission constraints as choice variable

- Transmission constraints assumed to be static
- Investments in interstate transmission & improvements in siting/planning of transmission part of IRA
- Can transmission upgrades be a choice variable?
  - Are nomogram constraints binding at key hours/seasons?

Thanks to the authors (and organizers)!