The Carbon Footprint of U.S. Monetary Policy

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Motivation & Research Question

- Central banks face growing pressure to address climate change (e.g., Network for Greening the Financial System)
- Environmental considerations **not yet explicitly** part of monetary policy
- Well established: higher production $\rightarrow$ more emissions (environmental literature), and higher interest rates $\rightarrow$ lower production (monetary economics)
- We do **not** know: by how much does monetary policy affect emissions?
- Existing studies (VAR, ARDL, cross-country) lack **causal identification**

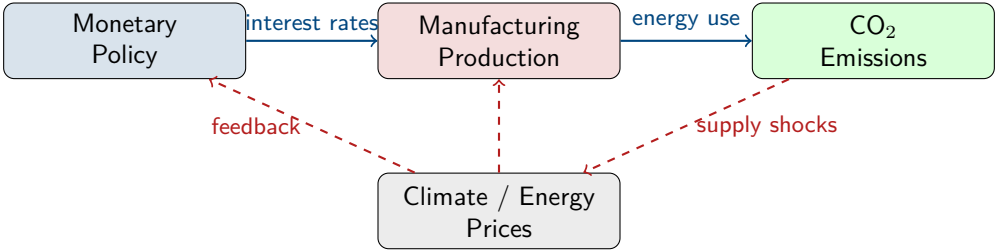
Research Question

How does a surprise change in the U.S. federal funds rate **causally** affect CO_2 emissions through manufacturing production?

Our Approach

Bartik instrumental variables — exploit the fact that states with more manufacturing are hit harder by interest rate shocks

Why Is Identification Hard?



- **Reverse causality:** emissions → energy prices → monetary policy
- **Omitted variables:** state politics, environmental regulations

Solution

Use **exogenous monetary policy shocks** (Romer & Romer, 2004) interacted with **state manufacturing shares** as an instrument

Data: Panel of 50 U.S. States, 1970–2019

Dependent Variables (EIA, state × year):

- **Industrial CO_2** (MMT) — process emissions: chemicals, cement, steel
- **Energy-related CO_2** (MMT) — combustion: electricity, transport, heating

Key Independent Variable (BEA):

- **Manufacturing earnings** — proxy for state production (state GDP unavailable for full period)

State-level Controls:

- Renewable energy fraction
- Population & employment rate
- Fossil fuel energy price
- Carbon intensity of energy supply

National-level Controls (secondary analysis):

- GDP growth, consumer sentiment, credit
- Macro uncertainty, exports, FDI, urbanization

$$N = 2{,}350 \quad \text{(50 states} \times \text{47 years)}$$

Empirical Model

Second stage — what we want to estimate:

$$\ln(\text{Emissions})_{st} = \alpha + \beta_1 \ln(\widehat{\text{Mfg earnings}})_{st} + \beta_2 X_{st} + \delta_s + \rho_t + \varepsilon_{st}$$

First stage — how the instrument drives manufacturing:

$$\ln(\text{Mfg earnings})_{st} = \gamma_0 + \gamma_1 \,\text{IV}_{st} + \gamma_2 X_{st} + \delta_s + \rho_t + \nu_{st}$$

- δ_s: state fixed effects — absorb time-invariant differences across states
- ρ_t: year fixed effects — absorb national trends
- Standard errors clustered at state level
- Estimator: **Two-Stage Least Squares (2SLS)**

Goal

β_1: causal elasticity of emissions w.r.t. manufacturing earnings, driven by **exogenous** monetary policy variation

The Bartik Instrument

Construction — following Bartik (1991), Blanchard & Katz (1992), Goldsmith-Pinkham et al. (2020):

$$\text{IV}_{st} = \underbrace{\text{RR Shock}_t}_{\text{national, exogenous}} \times \underbrace{\left(\frac{\text{Mfg Employment}_{st}}{\text{Total Employment}_{st}} \right)}_{\text{state mfg share}}$$

Key idea: same national shock hits states differently depending on how manufacturing-heavy they are ⇒ exogenous variation in earnings across states.

We use **current + 3 lags** of the instrument (following Romer & Romer, 2004).

Relevance: States with higher manufacturing shares are more sensitive to interest rate shocks ⇒ strong first stage expected

Exogeneity:

- RR shocks purge anticipated economic developments via Greenbook forecasts
- Lagged shocks cannot be affected by current conditions
- State/year FE + time-varying controls address remaining confounders

Romer & Romer (2004) Monetary Policy Shocks

- RR shocks = residuals from regressing intended fed funds rate changes on the Fed's **Greenbook** forecasts (GDP, inflation, unemployment)
- Strip out *anticipated* policy — isolate **surprise** tightenings/loosenings
- Updated through 2019 by Acosta (2023)
- Correlation with actual federal funds rate: 0.43
- We **also include** the federal funds intended rate as a control — captures anticipated changes, orthogonal to our instrument

Why surprises matter

Greenbook forecasts do not incorporate real-time environmental information ⇒ RR shocks are plausibly unrelated to emissions except through production

Plain language

We use only the part of interest rate changes that the Fed did **not** take in response to economic forecasts — these are true surprises

Instrument Validity

Strength (relevance):

- First-stage F-statistic = 17.7 (state-level)
- First-stage F-statistic = 10.7 (national controls)
- Both exceed conventional threshold of 10

Overidentification (exogeneity):

- Sargan test p-value = 0.767 (industrial)
- Sargan test p-value = 0.938 (energy-related)
- Cannot reject joint exogeneity

Plausible exogeneity — Conley et al. (2012):

- Standard IV assumes the instrument affects the outcome *only* through the endogenous variable
- In practice, this is untestable — Conley et al. allow the instrument to have a **small direct effect** on the outcome
- They compute bounds on the IV estimate under this relaxed assumption
- If 2SLS estimate lies within the bounds ⇒ results are robust even if exclusion restriction is slightly violated

	Industrial	Energy
2SLS estimate	1.714	0.951
95% lower bound	0.213	0.367
95% upper bound	1.826	0.965

Main Results: OLS vs. 2SLS

Dependent variable	OLS		2SLS	
	Industrial CO_2	Energy CO_2	Industrial CO_2	Energy CO_2
Log manufacturing earnings	0.678**	0.374**	1.714**	0.951**
	(0.025)	(0.011)	(0.187)	(0.092)
First-stage F-statistic			17.7	17.7
Sargan p-value			0.767	0.938
State & year FE	Yes			
State-level controls	Yes			
N	2,350			

- 2SLS **larger** than OLS — consistent with downward OLS bias
- 1% ↑ mfg earnings ⇒ industrial CO_2 ↑ 1.71%, energy CO_2 ↑ 0.95%

Interpretation

The true effect of production on emissions is **larger** than simple regressions suggest — OLS is downward biased

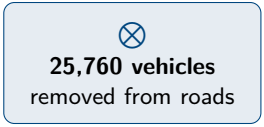
From Results to Policy: What Does a Rate Hike Do?

Transmission: surprise rate hike → lower manufacturing → lower emissions

First stage: 1 pp ↑ in surprise federal funds rate ⇒ mfg earnings ↓ 0.12% cumulatively (median state)

Second stage: This fall in manufacturing causes (cumulative over 4 years):

- 0.20% decline in **industrial** $CO_2 \approx$ 40,596 metric tons
- 0.11% decline in **energy-related** $CO_2 \approx$ 108,621 metric tons



Heterogeneity: Manufacturing-Intensive States Feel It More

A 1 pp surprise tightening reduces manufacturing earnings and emissions by:

	25th pct (low mfg)	**50th pct (median)**	75th pct (high mfg)
Mfg earnings decline	0.08%	**0.12%**	0.17%
Industrial CO_2 decline	0.13%	**0.20%**	0.30%
Energy-related CO_2 decline	0.07%	**0.11%**	0.17%

- 75th-percentile states experience **effects double** those at 25th percentile
- High mfg states: Michigan, Indiana, Ohio
- Low mfg states: Nevada, Hawaii, Wyoming

Why it matters

Monetary tightening has **uneven environmental consequences** across regions — relevant for distributional policy analysis

Robustness: Results Hold Across Specifications

1. **Durable manufacturing earnings** instead of total manufacturing
   - Sidesteps SIC $\rightarrow$ NAICS reclassification in 1998; consistent classification throughout
   - Results very similar in magnitude and significance
2. **Three lags only** (drop contemporaneous instrument)
   - Past shocks cannot be caused by current emissions — stronger time-precedence argument
   - Coefficients stable
3. **Sample ending in 2007** (pre-unconventional monetary policy)
   - Post-2008: QE, forward guidance, large-scale asset purchases may alter transmission
   - Results very similar — the emission channel predates unconventional policy

Bottom line

Findings are robust to alternative variable definitions, instrument lag structure, and sample period

Conclusion & Policy Implications

Main findings:

- A 1 pp surprise rate hike reduces manufacturing earnings by 0.12% (median state)
- Causes 0.20% decline in industrial CO_2 and 0.11% in energy-related CO_2
- $\equiv$ removing 25,760 vehicles or avoiding 45,575 tons of coal annually
- Manufacturing-intensive states bear **larger** reductions
- National channels (sentiment, credit, uncertainty) also matter

Limitations:

- No consistent long-run climate policy data for our period

Contributions:

- First Bartik-IV study of monetary policy $\rightarrow$ CO_2, exploiting **state-level heterogeneity**
- Stronger causal identification than VAR/ARDL/DID
- Complements literature on green monetary policy frameworks

Policy Implication

Monetary policy has significant **unintended environmental effects** — these should be part of comprehensive policy evaluations and climate strategies

Thank You

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Appendix: Descriptive Statistics

Variable	Mean	SD	Min	Max
Dependent variables				
Log industrial CO_2 emissions	2.344	1.205	−0.916	5.505
Log energy-related CO_2 emissions	4.213	0.984	1.411	6.529
Key regressor				
Log manufacturing earnings (2017$)	16.23	1.326	12.82	18.95
Instruments (Bartik × RR shock)				
Current value	0.005	0.115	−0.465	0.393
Lag 1	0.004	0.115	−0.465	0.393
Lag 2	−0.002	0.123	−0.476	0.393
Lag 3	−0.010	0.137	−0.650	0.393
Selected state-level controls				
Renewable energy fraction	0.099	0.110	0.005	0.573
Carbon intensity (kg CO_2/MMBtu)	59.17	11.50	25.60	85.70
Energy price ($)	11.48	5.050	3.042	57.55

Appendix: State-level Controls

Industrial CO_2 emissions:

- Renewable energy: positive (process emissions not displaced by electricity decarbonization)
- Energy price: **negative** (efficiency + fuel switching)
- Carbon intensity: **positive** (coal/oil reliance)
- Population & employment: **negative** (EKC-consistent: service sector shift)

Energy-related CO_2 emissions:

- Renewable energy: **negative** (directly displaces fossil fuel combustion)
- Energy price: **negative**
- Carbon intensity: **positive**
- Population & employment: **negative**

Key asymmetry

Renewables reduce energy-related but not industrial emissions — sectoral difference in emission sources

Appendix: National Channels

Core result unchanged: 1% ↑ mfg earnings ⇒ industrial CO_2 ↑ 1.69%, energy CO_2 ↑ 0.84%
National controls that matter:

- **Consumer sentiment** ↓ emissions (service sector growth, green preferences)
- **Credit** ↑ energy CO_2 (non-renewable investment dominates)
- **Macro uncertainty** ↓ emissions (production cut > clean energy cut)
- **Exports** ↓ industrial CO_2 (energy-efficient exporting sectors)
- **Urbanization** ↑ emissions (infrastructure, density, consumption)

Fed funds intended rate

Not significant in 2nd stage — anticipated changes have no long-run real effects (money neutrality)

	Industrial	Energy
2SLS $\hat{\beta}_1$	1.692^{**}	0.835^{**}
	(0.240)	(0.106)
F-stat	10.71	
Sargan p	0.848	0.798

Appendix: Robustness — Durable Manufacturing

- Replace total manufacturing earnings with **durable goods manufacturing earnings**
- Durable goods: consistent industry classification across SIC and NAICS systems
- Drop the post-1998 industry classification dummy
- Results remain similar: same signs, comparable magnitudes, same significance levels

Appendix: Robustness — Three Lags Only

- Use only lags 1–3 of the instrument (drop contemporaneous interaction)
- Time precedence: past monetary shocks cannot be influenced by current emissions
- Coefficients on manufacturing earnings remain stable
- F-statistics remain sufficient

Appendix: Robustness — Sample Ending 2007

- Post-2008 unconventional monetary policy (QE, forward guidance, LSAP) may alter transmission mechanisms
- Estimate on 1970–2007 subsample (conventional monetary policy period only)
- Results very similar in sign, magnitude, and significance
- The emission channel is **not** driven by the post-2008 period

Appendix: Environmental Kuznets Curve

- EKC hypothesis (Grossman & Krueger, 1995): emissions rise then fall as income grows
- Our finding: population and employment **negatively** affect emissions in the U.S.
- Consistent with EKC at high-income levels: structural shift from manufacturing toward services
- Urbanization **increases** emissions — contrary to simple EKC — due to infrastructure and consumption demands