Macroeconomic Effects of the Universe of EPA Regulations

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What Do We Do?

Question: What are aggregate effects of environmental regulations?

Empirically

- Construct industry-specific index of EPA (federal) regulations
- Index captures the universe of active federal regulations in CFR
- Explore link b/w toxic releases and regulations
  - at facility & facility-chemical level

Quantitative analysis

- Build dynamic GE model of mnf sector in the U.S.
- Industries are linked through I-O network
- Explore cross-elasticities of pollution to regulations
- Transition dynamics: impact of regulations on aggregate emissions

Findings: Empirics

Index of (federal) EPA regulations

- Time-varying at NAICS 3-digit level
- Time period covered: 1999-2021
- Reflects the universe of active regulations
- Index captures binding obligations and exposure to regulations

Leverage data on toxic releases from TRI

- 1 std $\uparrow$ in index associated with 11.7% $\downarrow$ in releases
- Results validated using another data (NEI)

Findings: Model

Key results

- Aggregate pollution decreased by $\approx 15\%$ over 1999-2021
- Substantial heterogeneity across industries
- I-O are crucial for propagating regulations across the economy
  - w/o I-O cross-elasticities are typically negative
  - I-O linkages increase many cross-elasticities
  - leads to unintended consequences of regulations
- W/o GE the effect of regulations is larger

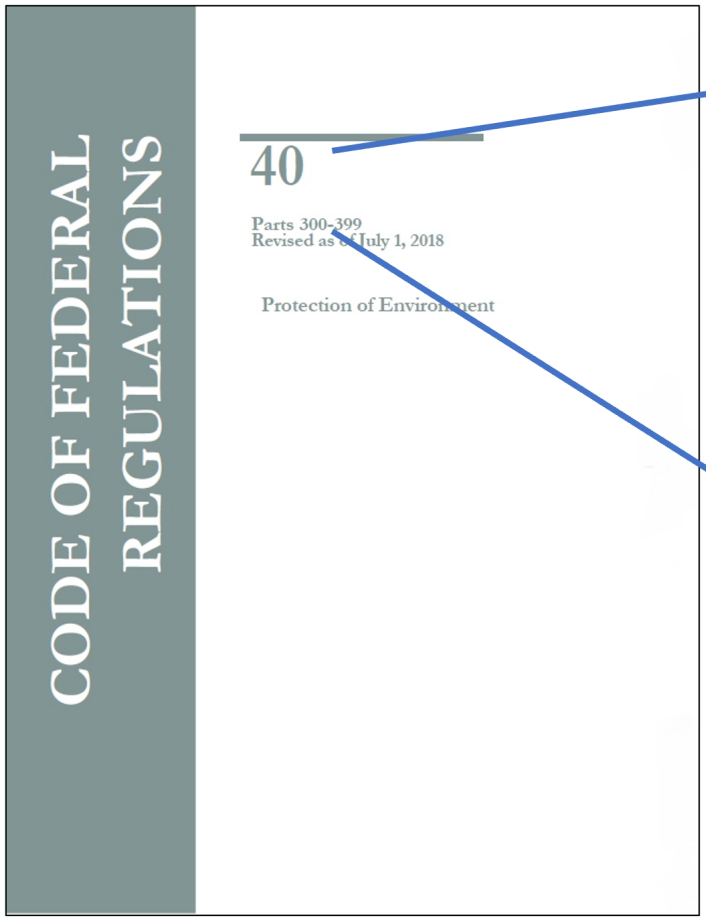
Work-in-progress

- Role of dynamic effect (capital can be adjusted right away)
- Role of changing technology

▸ Related literature

Outline

EPA Index



- Title 40 has the universe of **active** EPA regulations, including Parts 1-1,099 (2020).

Title 40 → Parts: cover particular topics → Sections: correspond to rule numbers

e.g., Part 60 Standards of performance for new stationary sources

Section 60.13 Monitoring requirements.

EPA Index

What it captures

- Total EPA regulation restrictions for each industry in each year
- Based on *all effective regulation text* from EPA since 1999

Data source

- Count of restriction words in CFR text
  - *shall, must, may not, prohibited, cannot, forbidden, required*
- Exposure of regulation text to each industry
  - count how many times a part is mentioned by EPA and in FR

Construction

$$Reg_{j,t}^{Fed} = \frac{\sum_p Exposure_{j,p,t} \times Restriction_{p,t}}{\sum_p WordCount_{p,t}}$$

Toxic Releases Inventory (TRI)

TRI commenced in 1987

- Tracks toxic chemicals that may cause harm to human health/environment
- Part of the Emergency Planning and Community Right-to-Know Act

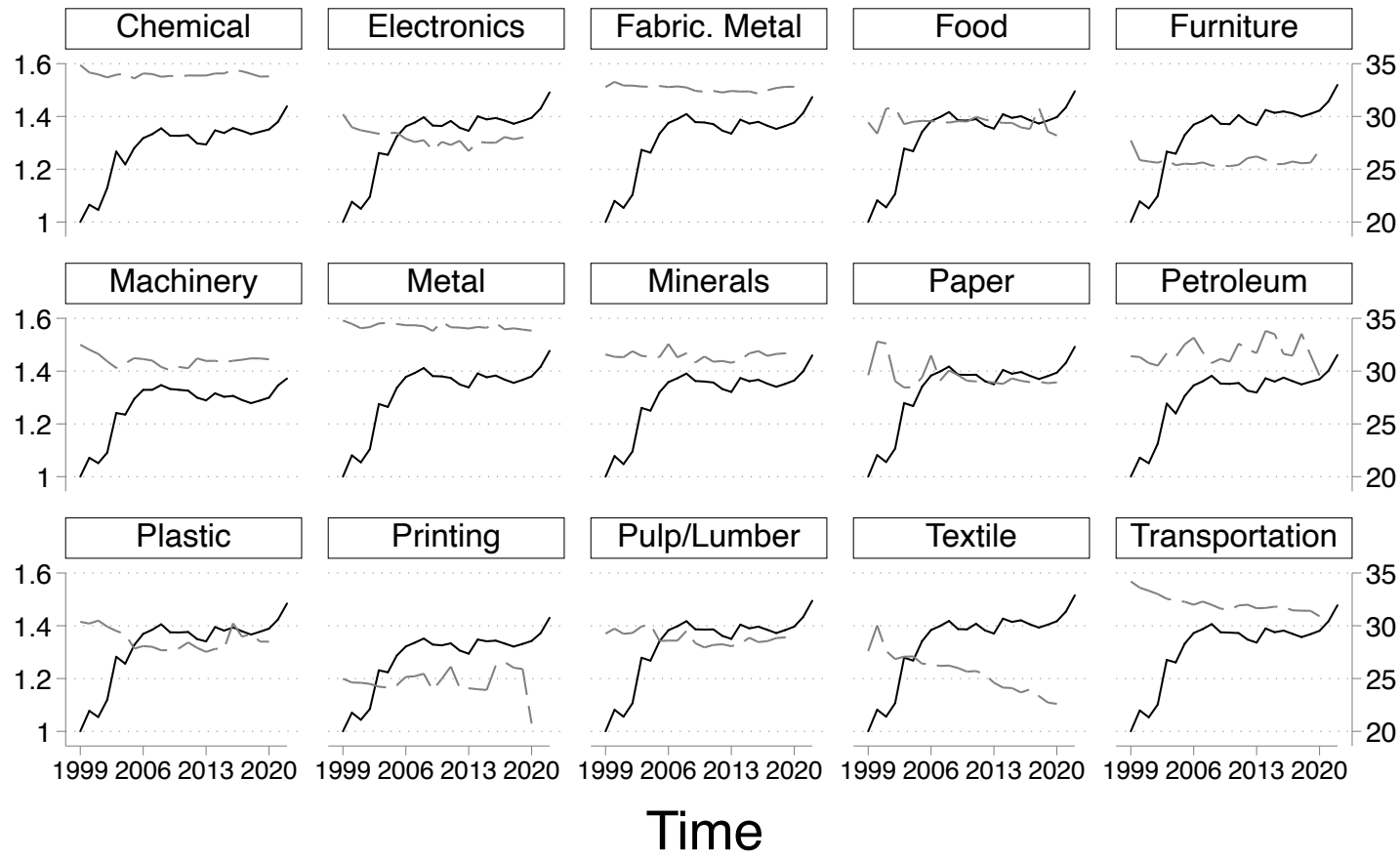
Coverage of facilities:

- Certain industries (mnf included)
- $\geq$ 10 employees
- Release of at least one chemical is above threshold

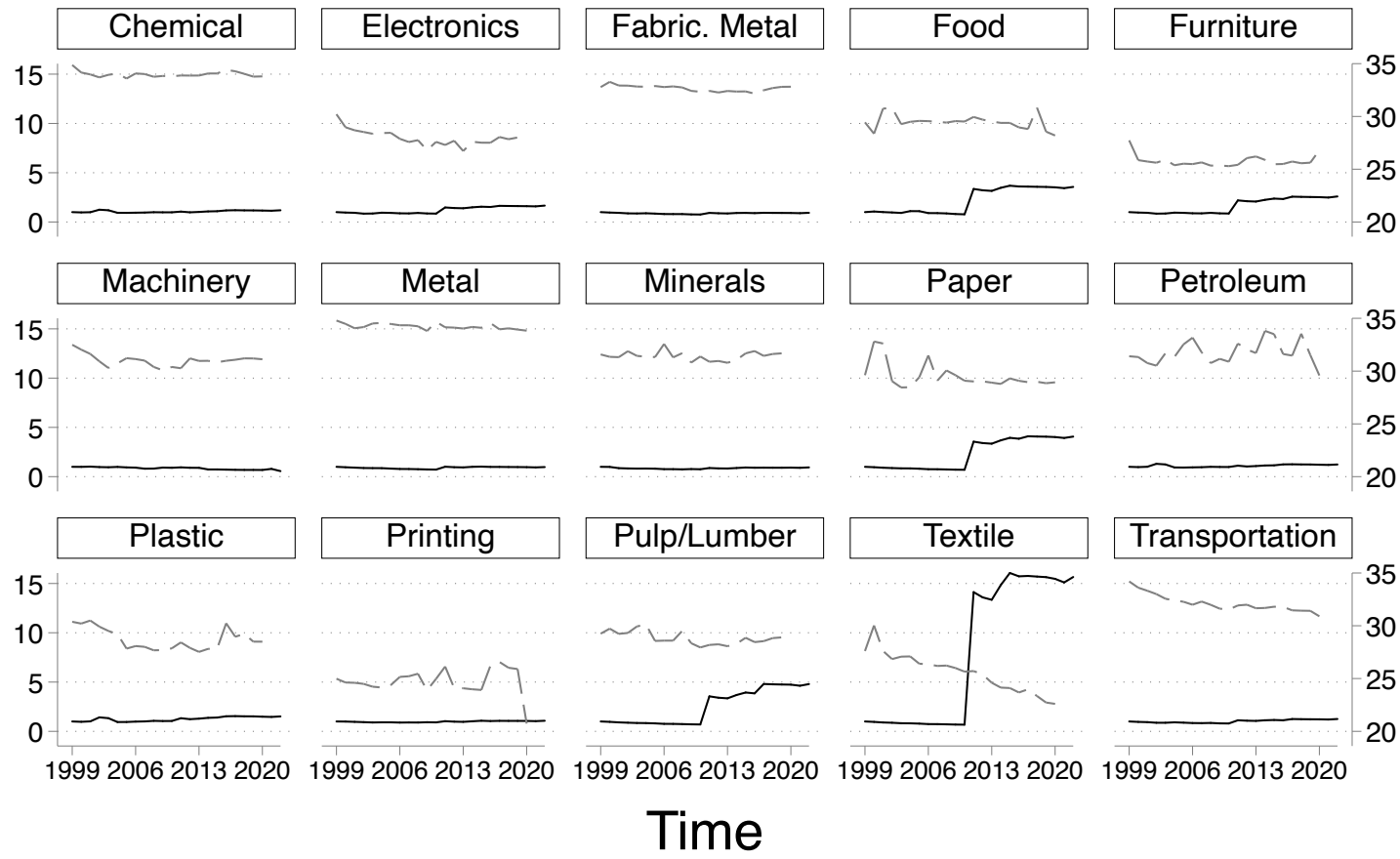
Coverage of chemicals changed over time

- Do robustness restricting to chemicals covered throughout
- Use toxicity weights (Risk-Screening Environmental Indicators)
- Toxicity $= \max\{$Inhalation toxicity, Oral toxicity$\}$
- It is inverse of "exposure likely to be w/o appreciable health risk over lifetime"

EPA Index and Toxic Releases



EPA Index (w/o part 63) and Toxic Releases



EPA Index and Toxic Releases

$$\log\left(TRI_{i,t+k}\right) = \alpha + \beta \Delta Reg^{Fed}{}_{j,t} + \epsilon_{i,t}$$

- Industry & year FE, SE double clustered at industry-year

Panel A: All Industries					
Years Ahead	0	1	2	3	4
ΔReg^{Fed}	-0.734*	-0.696*	-0.612	-0.611	-0.556
	(0.416)	(0.404)	(0.372)	(0.362)	(0.344)
Observations	443,496	403,732	367,453	334,052	303,232
Adj R^2	0.170	0.171	0.171	0.171	0.171
Panel B: Manufacturing Industries					
Years Ahead	0	1	2	3	4
ΔReg^{Fed}	-1.332**	-1.292**	-1.152**	-1.127**	-1.035**
	(0.504)	(0.480)	(0.439)	(0.439)	(0.415)
Observations	395,132	359,950	327,741	298,066	270,726
Adj R^2	0.137	0.137	0.135	0.134	0.133

Interpretation: 1 std $\uparrow$ in index associated with 21% $\downarrow$ in releases

▸ Summary statistics

EPA Index and Toxic Releases: Dynamic Effect

	log $TRI_{i,t}$
ΔReg_t^{Fed}	-1.032**
	(0.444)
ΔReg_{t-1}^{Fed}	-1.016*
	(0.564)
ΔReg_{t-2}^{Fed}	-0.561
	(0.368)
ΔReg_{t-3}^{Fed}	-0.313
	(0.234)
ΔReg_{t+1}^{Fed}	-0.237
	(0.416)
ΔReg_{t+2}^{Fed}	0.085
	(0.423)
ΔReg_{t+3}^{Fed}	-0.100
	(0.345)
Cons	5.981***
	(0.093)
Observations	378,485
Adj R^2	0.136
Industry and Year FE	Y

EPA Index and Toxic Releases: Chemical Level

	log TRI_{ict+k}				
Years Ahead	0	1	2	3	4
ΔReg^{Fed}	-0.125*	-0.098*	-0.105**	-0.075**	-0.086*
	(0.064)	(0.049)	(0.037)	(0.032)	(0.045)
Cons	3.916***	3.970***	4.020***	4.064***	4.108***
	(0.004)	(0.003)	(0.002)	(0.002)	(0.003)
Observations	1,222,365	1,090,204	976,749	876,541	786,620
Adj R^2	0.695	0.702	0.707	0.712	0.716
Plant FE	Y	Y	Y	Y	Y
Year-by-chemical FE	Y	Y	Y	Y	Y

▸ By type of pollutant

EPA Index and Air Pollutants: Evidence from NEI

Details

- Sample restricted to mnf industries
- Data frequency is 3 years
- Six major air pollutant: CO, NOX, VOC, SO2, PM10, PM2.5.

	$\log NEI_{it}$		
ΔReg^{Fed}	-0.775***	-0.389**	-0.334**
	(0.169)	(0.139)	(0.155)
Cons	-0.339***	-0.345***	-0.222***
	(0.002)	(0.002)	(0.002)
Observations	387,198	385,892	359,376
Adj R^2	0.232	0.745	0.925
Plant FE		Y	
Industry FE	Y		
Plant-by-pollutant FE			Y
Year-by-pollutant FE	Y	Y	Y

Outline

Model: Environment

Agents:

- N competitive sectors, one firm in each sector
- Representative household
- Capital good producer

Production sector:

- Firms use capital, labor, intermediate inputs, and dirty factor
- Capital choice is intertemporal
- Take prices as given

Representative household:

- Consumes, supplies labor, owns firms

Capital good producer:

- Combines capital and labor to produce investment good

Model: Firms

- N sectors, production function, $y_j = A_j k^{\alpha_j} n^{\nu_j} \left(\prod_{s=1}^{N} m_s^{\omega_j^s} \right)^{\kappa_j} d^{\gamma_j}$
- Operating profits:

$$\pi_{jt}(k) = \max_{n, \{m_s\}, d \geq 0} P_{jt} A_{jt} k^{\alpha_j} n^{\nu_j} \left(\prod_{s=1}^{N} m_s^{\omega_j^s} \right)^{\kappa_j} d^{\gamma_j} - W_t n - \sum_{s=1}^{N} P_{st} m_s - \tau_{jt} d$$

- Value at start of period:

$$v_{jt}(k) = \pi_{jt}(k) + \max_{k' \geq 0} \Big\{ - Q_t(k' - (1-\delta)k) - W_t \times AC(k, k') + \\ + \mathbb{E}_t \left[M(\mathbf{S}, \mathbf{S}') v_{jt+1}(k') \right] \Big\}$$

- Dividends:

$$D_{jt}(k) = \pi_{jt}(k) - Q_t(k' - (1-\delta)k) - W_t \times AC(k, k')$$

Model: Household and Capital Good Producer

Preferences and budget

- Value consumption, labor inelastic $U = \log\left(\prod_{s=1}^{N} c_s^{v_s}\right)$
- Expenditure shares $\{v_s\}_{s=1}^{N}$ taken off the data
- Labor supplied inelastically
- Budget constraint

$$\sum_{s=1}^{N} P_{st} c_{st} \leq W_t + \sum_{s=1}^{N} D_{st}$$

Capital good producer

- Technology: $K_K^{\alpha_K} N_K^{\beta_K}$, $\alpha_k + \beta_k = 1$
- Profit maximization pins down $Q_t = \frac{W_t}{\beta_K K_K^{\alpha_K} N_K^{\beta_K - 1}}$

Outline

Parameterization: Technology

Production functions at NAICS 3-digit level ($N = 15$)

- Combine TRI with ASM/CM
- No unique identifier
  - source plant name/address from Business Registrar
  - exact (NAICS & state) and fuzzy matching (name, address, zip, city)
- About 70% of TRI facilities matched to Census sample
- Estimate $\{\widehat{\alpha}_j, \widehat{\nu}_j, \widehat{\kappa}_j, \widehat{\gamma}_j\}_{j=1}^{15}$
- Experimented with OP, LP and simple "naive" regressions
- LP treating d as a state is our preferred method

Technology has changed over time

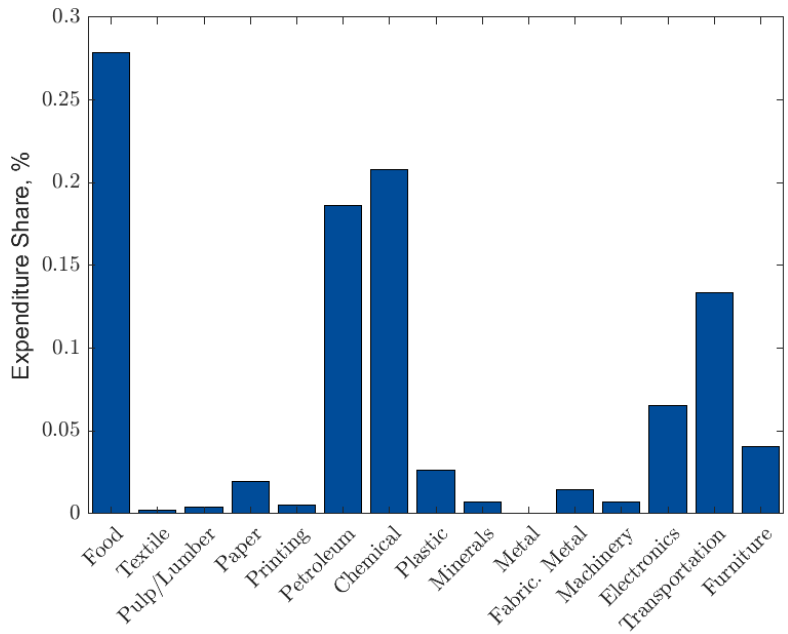
- Re-estimated for early (1987-2002) and late (2003-2019) subperiods

▸ Estimates: 1987-2019 ▸ Estimates: 1987-2002 ▸ Estimates: 2003-2019

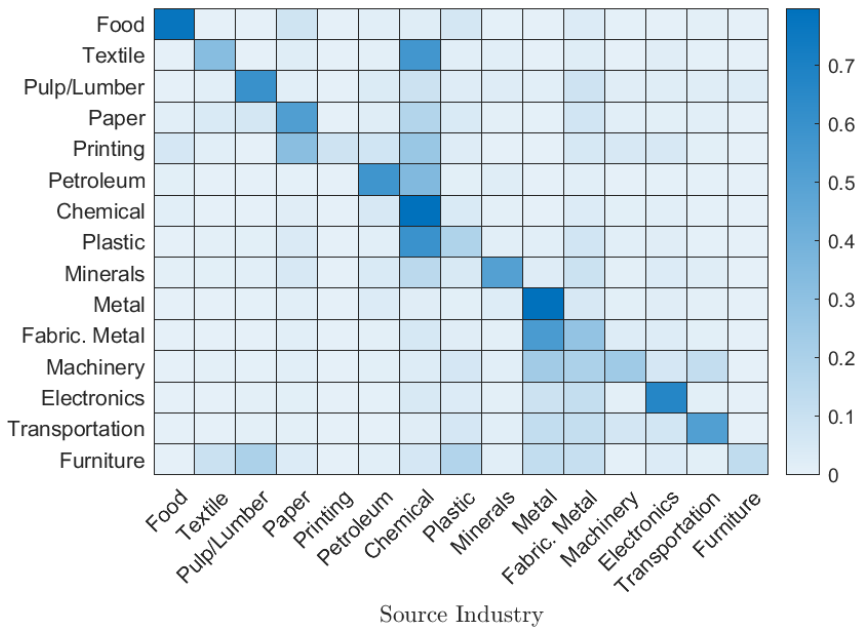
Parameterization (cont'd)

Technology and preferences

- Expenditure shares $\{v_j\}$ from BEA
- Input-Output matrix Ω from aggregate data (we model mnf sector)
- Sectoral productivities $\{A_j\}$ chosen to hit emp. shares



Expenditure shares $\{v_j\}$



IO matrix Ω

Parameterization (cont'd)

Price of dirty factor governed by EPA regulations $\tau_{jt} = \zeta_0^j e^{\zeta_1 EPA_{jt}}$

- From FOC (taking logs and first-diff):

$$\Delta \log \left(\frac{y_{it}}{d_{it}} \right) = \zeta_1 \Delta EPA_{j(i)t} + \eta_{it}$$

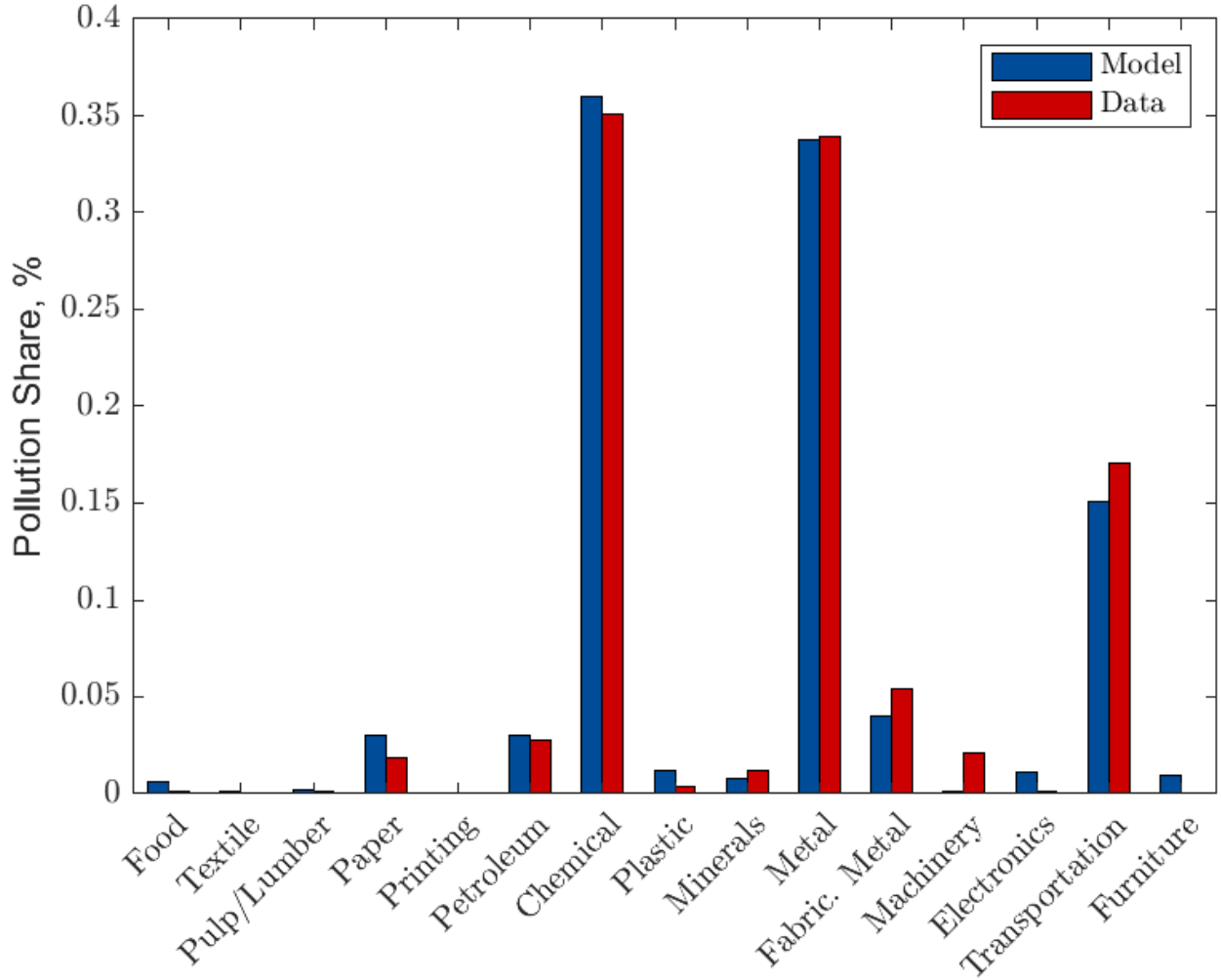
- Compustat-based estimate $\widehat{\zeta_1} = 0.278^{***}$

	(1)	(2)
$\widehat{\zeta_1}$	0.165^{**}	0.278^{***}
	(0.070)	(0.054)
Sample	All	Mnf
Industry & Year FE	✓	✓
R^2	0.090	0.086

Parameterization (cont'd)

Level parameters $\{\zeta_0^j\}$:

- Target distribution of pollution in 1999



Outline

Cross-Sectoral Elasticities: Partial Equilibrium

Response of pollution to a 10% increase in τ_j in a given industry

- Other prices held fixed

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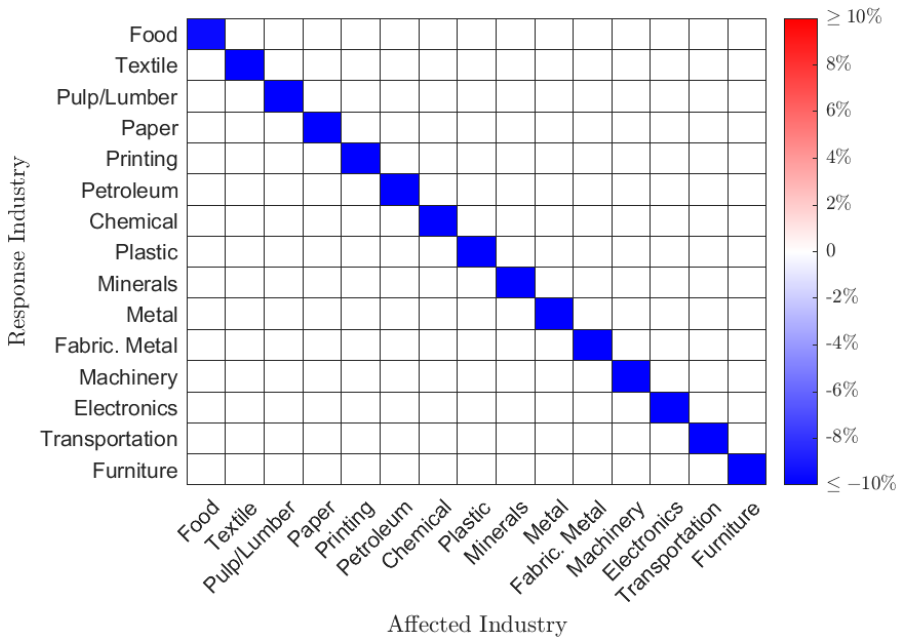

$$\Omega = \mathbf{I}$$

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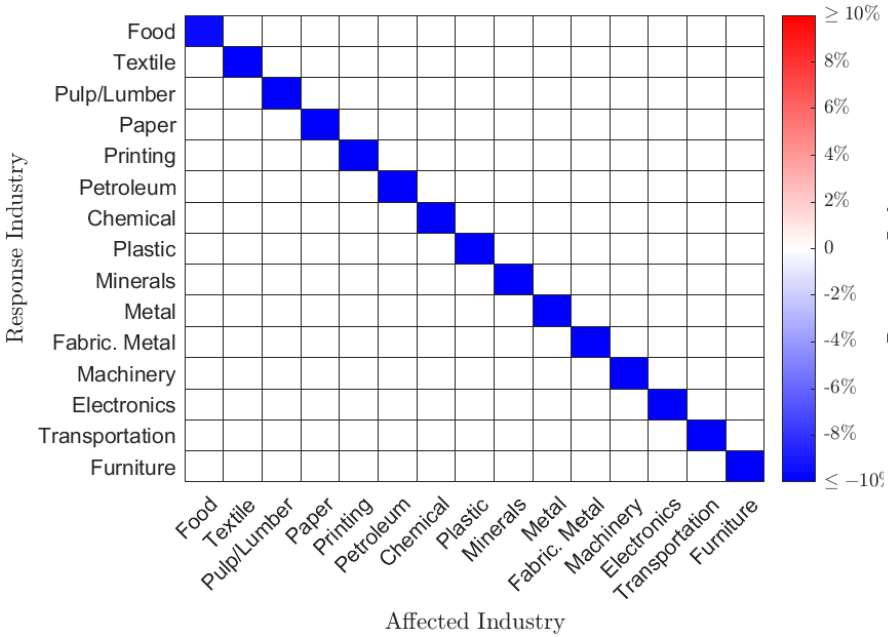

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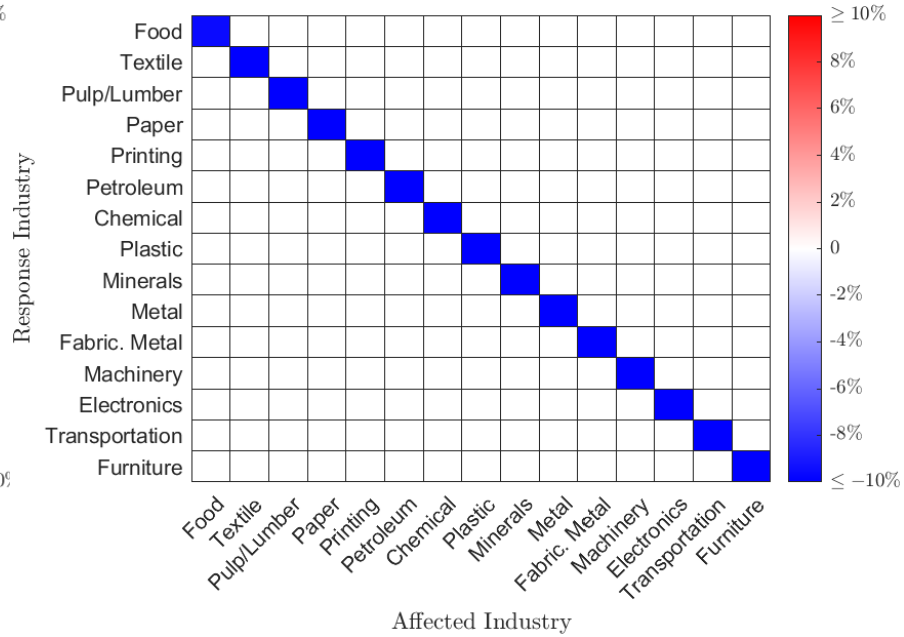

Calibrated Ω

Cross-Sectoral Elasticities: General Equilibrium

Response of pollution to a 10% increase in τ_j in a given industry

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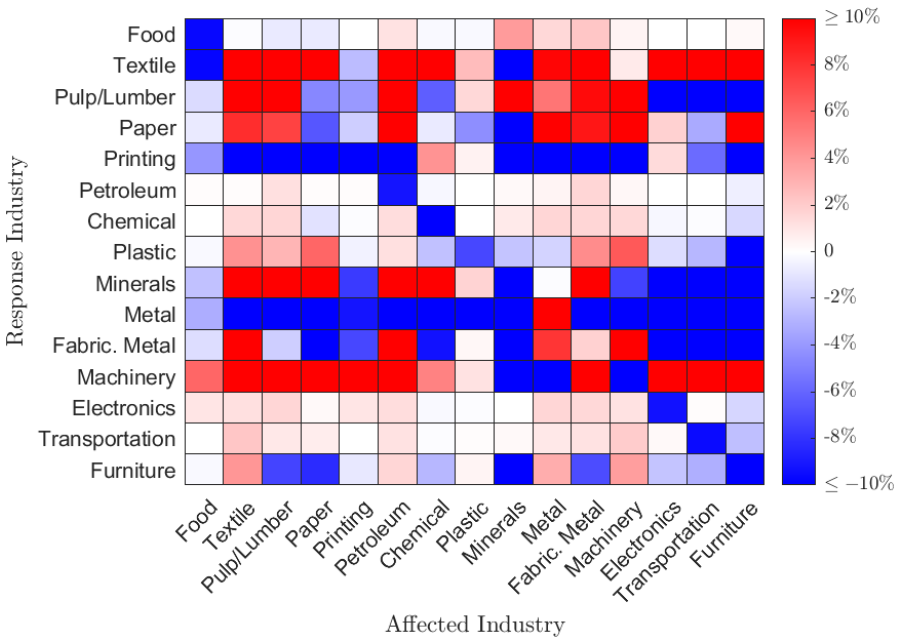

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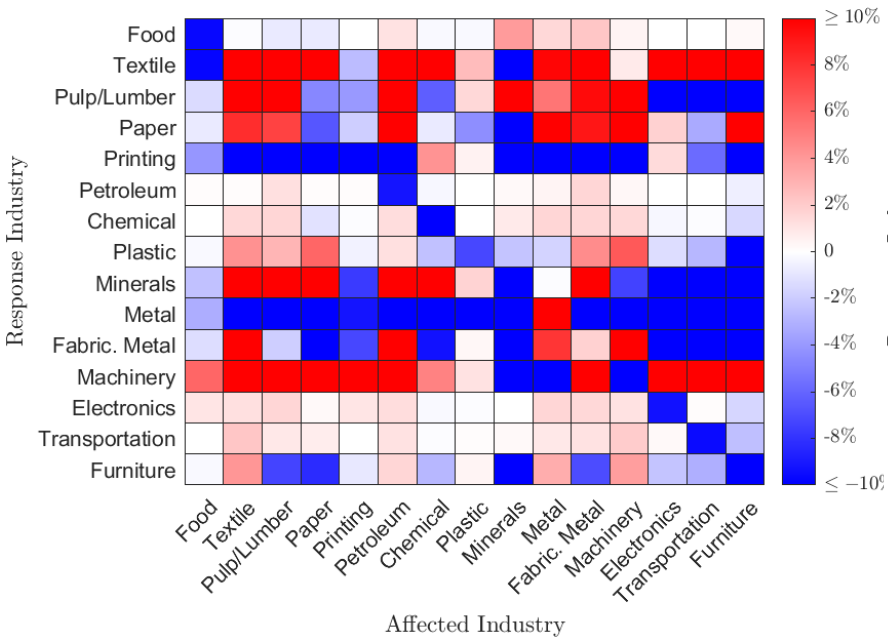

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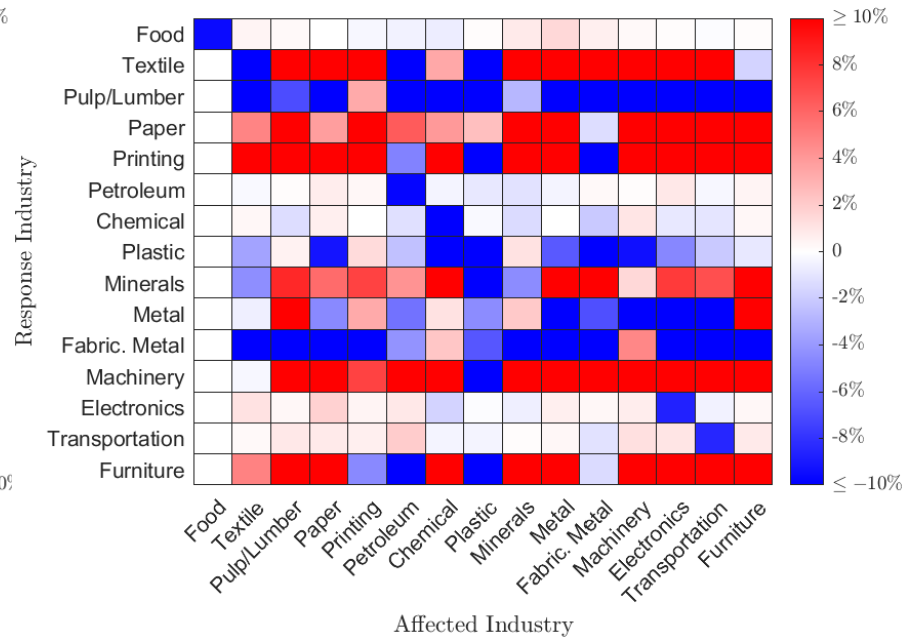

Calibrated Ω

Outline

EPA Regulations and Toxic Releases

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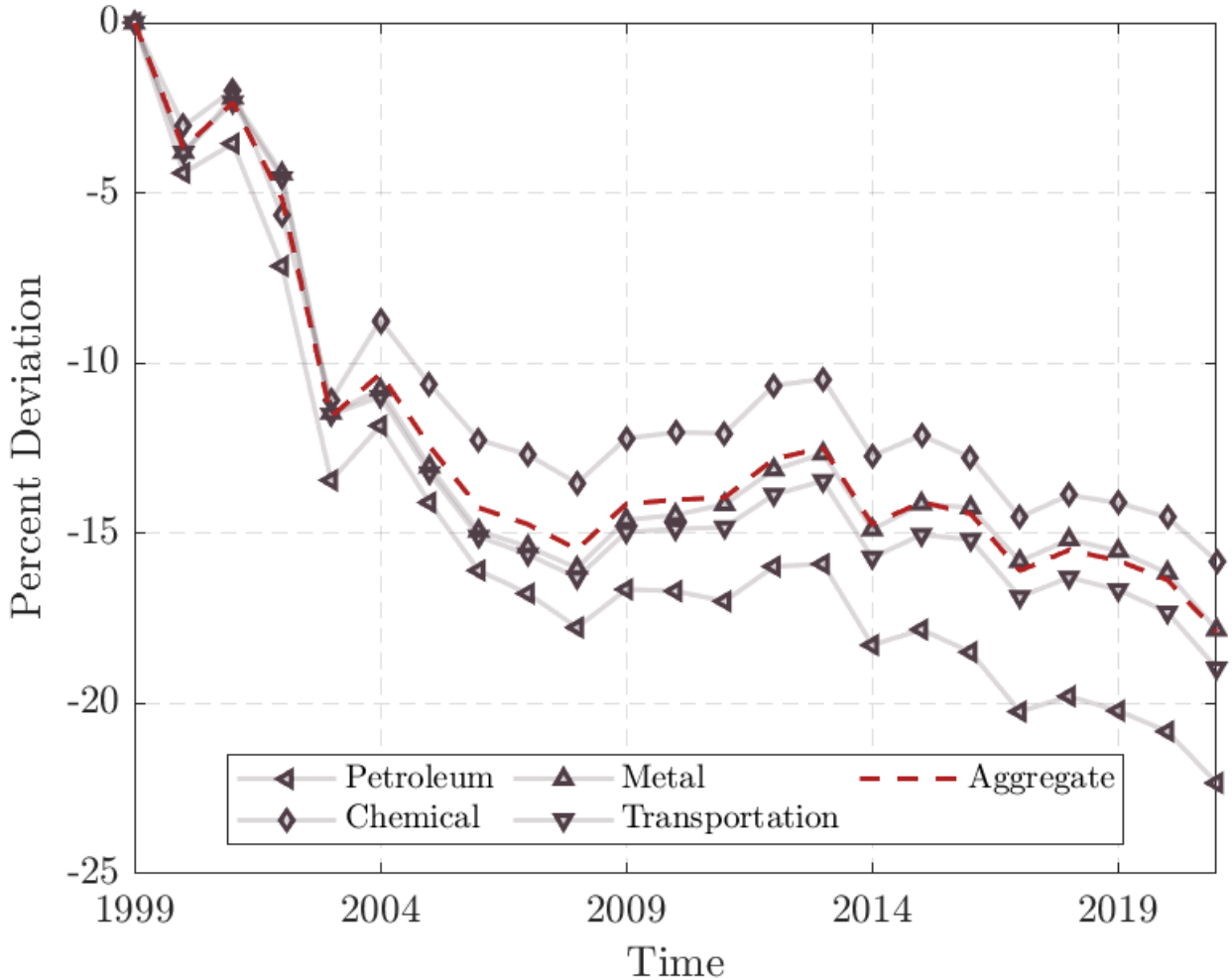
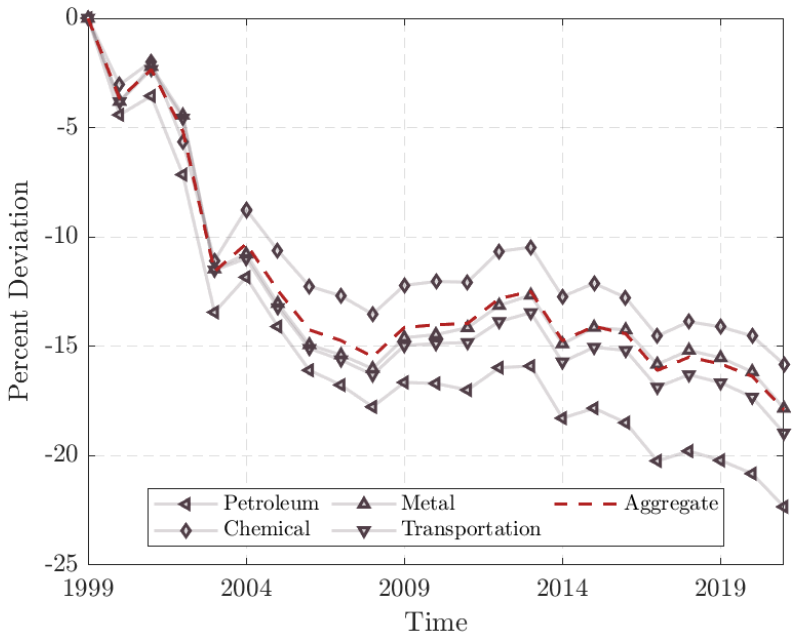


Role of I-O Linkages



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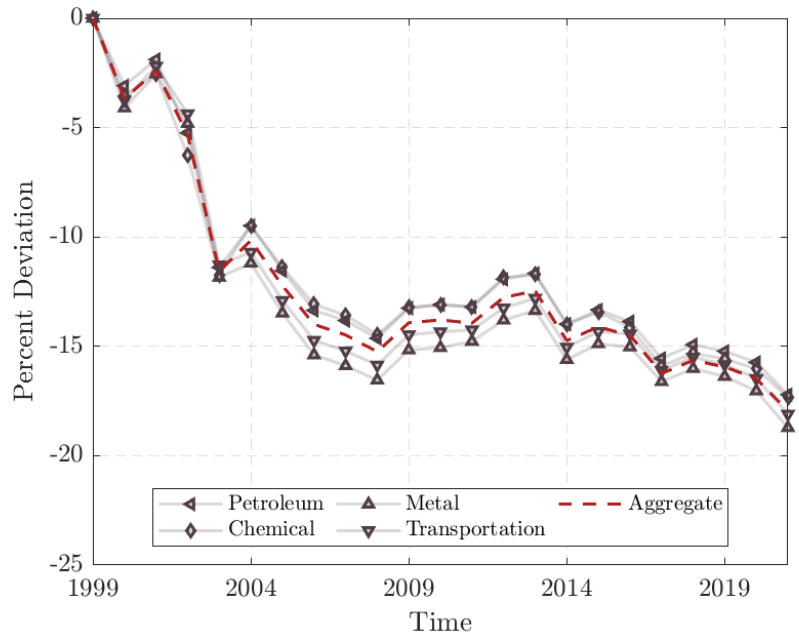
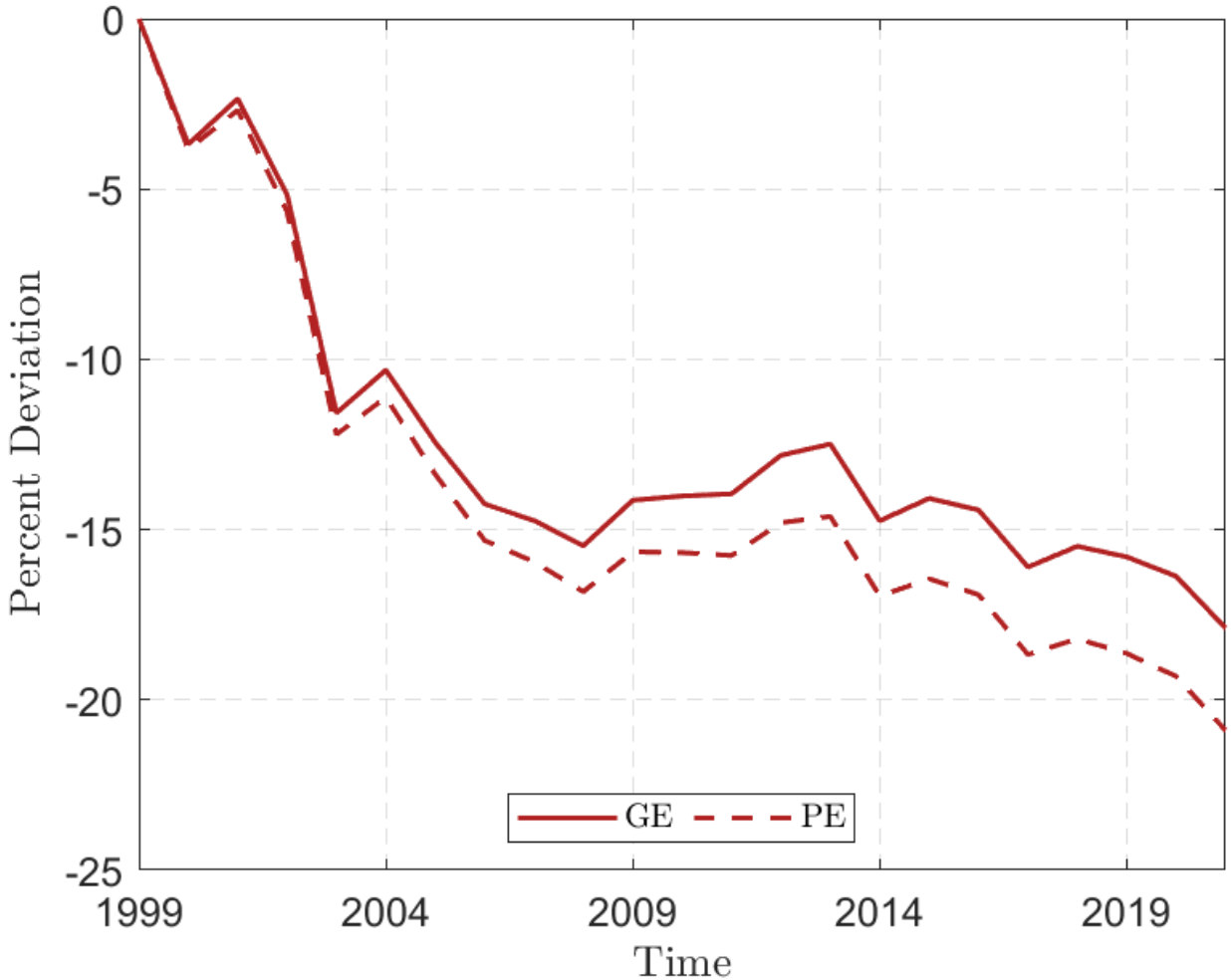


$\Omega = \mathbf{I}$

GE vs. PE


0
-5
-10
-15
-20
-25
Percent Deviation
1999
2004
2009
2014
2019
Time
GE
PE

Conclusion

Summary:

- Studied the impact of environmental regulations on toxic releases
- Summarized all effective federal regulations with an index
- Developed a GE model of mnf sector with I-O linkages
- Found that EPA regulations account for a 15% decline in releases

Road ahead:

- Construct index of state regulations
- Role of changing technology
- Role of the dynamic effect
- Federal vs. state regulations

Appendix

Summary Statistics

	Mean	SD	10%	50%	90%
ΔReg^{Fed}	0.06	0.16	-0.03	0.01	0.20
$\log(TRI)$	7.91	3.89	2.30	8.65	12.12
$\Delta \log(Sale/TRI)$	5.95	4.44	0.00	6.64	14.76

Back

Identification of $\widehat{\zeta_1}$

	(1)	(2)
$\widehat{\zeta_1}$	0.165^{**}	0.278^{***}
	(0.070)	(0.054)
Sample	All	Mnf
Industry & Year FE	✓	✓
R^2	0.090	0.086

Back

Production Function Estimates: 1987-2019

Industry	NAICS	Capital ($\widehat{\alpha}$)	Labor ($\widehat{\nu}$)	Materials ($\widehat{\kappa}$)	Pollution ($\widehat{\gamma}$)
Food	311	0.193	0.145	0.416	0.001
		(0.0243)	(0.0080)	(0.0186)	(0.0008)
Textile	313	0.390	0.298	0.464	0.004
		(0.1616)	(0.0263)	(0.0488)	(0.0023)
Pulp/Lumber	321	0.224	0.161	0.552	0.003
		(0.0418)	(0.0097)	(0.0238)	(0.0011)
Paper	322	0.337	0.229	0.507	0.006
		(0.0547)	(0.0180)	(0.0352)	(0.0017)
Printing	323	0.052	0.364	0.437	0.003
		(0.0534)	(0.0216)	(0.0489)	(0.0052)
Petroleum	324	0.143	0.217	0.569	0.005
		(0.0740)	(0.0152)	(0.0386)	(0.0022)
Chemical	325	0.367	0.199	0.470	0.002
		(0.0314)	(0.0073)	(0.0152)	(0.0011)
Plastic	326	0.194	0.239	0.487	0.002
		(0.0194)	(0.0100)	(0.0182)	(0.0011)
Minerals	327	0.199	0.323	0.421	0.008
		(0.0354)	(0.0108)	(0.0162)	(0.0013)
Metal	331	0.295	0.266	0.482	0.004
		(0.0701)	(0.0108)	(0.0166)	(0.0013)
Fab. Metal	332	0.270	0.318	0.412	0.003
		(0.0278)	(0.0082)	(0.0137)	(0.0007)
Machinery	333	0.426	0.285	0.525	0.002
		(0.0992)	(0.0111)	(0.0266)	(0.0009)
Electronics	334	0.243	0.085	0.457	0.001
		(0.1051)	(0.0257)	(0.0237)	(0.0024)
Transportation	336	0.143	0.282	0.482	0.003
		(0.0352)	(0.0127)	(0.0189)	(0.0009)
Furniture	337	0.138	0.228	0.515	0.003
		(0.0886)	(0.0245)	(0.0391)	(0.0026)

Back

Production Function Estimates: 1987-2002

Industry	NAICS	Capital ($\widehat{\alpha}$)	Labor ($\widehat{\nu}$)	Materials ($\widehat{\kappa}$)	Pollution ($\widehat{\gamma}$)
Food	311	0.158	0.150	0.514	-0.001
		(0.1203)	(0.0104)	(0.0465)	(0.0011)
Textile	313	0.369	0.279	0.540	0.000
		(0.1527)	(0.0281)	(0.0569)	(0.0026)
Pulp/Lumber	321	0.162	0.208	0.635	-0.001
		(0.0649)	(0.0126)	(0.0506)	(0.0012)
Paper	322	0.255	0.253	0.666	0.001
		(0.0945)	(0.0323)	(0.0794)	(0.0025)
Printing	323	0.034	0.319	0.423	-0.002
		(0.0740)	(0.0263)	(0.0639)	(0.0074)
Petroleum	324	0.065	0.175	0.760	0.003
		(0.0717)	(0.0195)	(0.0396)	(0.0032)
Chemical	325	0.197	0.178	0.574	-0.001
		(0.0897)	(0.0109)	(0.0250)	(0.0018)
Plastic	326	0.187	0.226	0.550	0.003
		(0.0591)	(0.0128)	(0.0336)	(0.0015)
Minerals	327	0.382	0.277	0.355	0.003
		(0.0846)	(0.0188)	(0.0363)	(0.0018)
Metal	331	0.150	0.279	0.517	0.000
		(0.0545)	(0.0104)	(0.0369)	(0.0013)
Fab. Metal	332	0.190	0.341	0.394	0.003
		(0.0508)	(0.0094)	(0.0230)	(0.0010)
Machinery	333	0.320	0.274	0.617	0.003
		(0.1504)	(0.0191)	(0.0298)	(0.0014)
Electronics	334	0.123	0.301	0.541	0.004
		(0.1387)	(0.0295)	(0.0451)	(0.0035)
Transportation	336	0.160	0.340	0.512	0.000
		(0.0614)	(0.0175)	(0.0289)	(0.0016)
Furniture	337	0.138	0.221	0.558	0.004
		(0.1041)	(0.0349)	(0.0495)	(0.0031)

Back

Production Function Estimates: 2003-2019

Industry	NAICS	Capital ($\widehat{\alpha}$)	Labor ($\widehat{\nu}$)	Materials ($\widehat{\kappa}$)	Pollution ($\widehat{\gamma}$)
Food	311	0.156	0.156	0.386	0.001
		(0.0282)	(0.0102)	(0.0203)	(0.0011)
Textile	313	0.148	0.402	0.389	0.009
		(0.2753)	(0.0437)	(0.0772)	(0.0049)
Pulp/Lumber	321	0.208	0.163	0.529	0.007
		(0.0449)	(0.0148)	(0.0291)	(0.0016)
Paper	322	0.368	0.262	0.464	0.010
		(0.0433)	(0.0283)	(0.0344)	(0.0031)
Printing	323	0.068	0.402	0.518	0.007
		(0.0594)	(0.0326)	(0.0582)	(0.0081)
Petroleum	324	0.077	0.217	0.558	0.004
		(0.1541)	(0.0193)	(0.0432)	(0.0035)
Chemical	325	0.382	0.205	0.441	0.003
		(0.0340)	(0.0100)	(0.0159)	(0.0017)
Plastic	326	0.193	0.269	0.464	0.002
		(0.0272)	(0.0143)	(0.0206)	(0.0014)
Minerals	327	0.174	0.343	0.426	0.011
		(0.0174)	(0.0120)	(0.0185)	(0.0019)
Metal	331	0.307	0.282	0.476	0.007
		(0.0968)	(0.0141)	(0.0215)	(0.0018)
Fab. Metal	332	0.268	0.323	0.411	0.002
		(0.0349)	(0.0107)	(0.0140)	(0.0009)
Machinery	333	0.405	0.308	0.500	0.001
		(0.1085)	(0.0135)	(0.0254)	(0.0011)
Electronics	334	0.802	0.177	0.355	0.000
		(0.2054)	(0.0379)	(0.0345)	(0.0036)
Transportation	336	0.189	0.297	0.467	0.003
		(0.0405)	(0.0168)	(0.0212)	(0.0012)
Furniture	337	0.171	0.253	0.483	0.004
		(0.1215)	(0.0370)	(0.0592)	(0.0037)

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Related Literature

Environmental regulations & pollution

- Greenstone List Syverson 2012, Shapiro Walker 2018, Colmer et al. 2013
  - construct a measure of regulations over 4 decades
  - both federal and at state level

Firm dynamics in environmental context

- Shapiro Walker 2018
  - dynamic, multisector model with I-O linkages

Models with production network

- Bigio La'O 2020, vom Lehn Winberry 2022
  - develop a dynamic model in general equilibrium
  - solve the model globally, analyze transition dynamics

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EPA Index and Toxic Releases: Type of Pollutant

Mnf industries

- Strongest effect for air pollutants

	log TRI_{Air}			log TRI_{Water}			log TRI_{Land}		
Years Ahead	0	1	2	0	1	2	0	1	2
ΔReg^{Fed}	-1.162**	-1.154**	-1.035**	-0.037	-0.038	-0.039	0.027	-0.013	-0.043
	(0.445)	(0.437)	(0.388)	(0.062)	(0.051)	(0.049)	(0.054)	(0.055)	(0.051)
Cons	4.734***	4.775***	4.801***	0.592***	0.610***	0.627***	0.408***	0.415***	0.422***
	(0.020)	(0.020)	(0.017)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Observations	395,131	359,946	327,745	395,131	359,946	327,745	395,131	359,946	327,745
Adj R^2	0.142	0.142	0.141	0.108	0.111	0.113	0.052	0.055	0.057
Industry and Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y

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