The Unintended Externalities of an Environmental Regulation: Evidence from the NOx Budget Trading Program

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The Story

*Cracking down on **carbon** is a bit like **squeezing a balloon**. Press too hard all at once and it may pop, but squeeze only in one corner and the air will simply flow to where there is less pressure.*

- The Economist, December 4, 2021

The Story

- Regional environmental regulations can induce **negative spillover**
  - **Directly regulated** firms' emissions are shown to exhibit internal substitutions of chemicals/plants.

- We examine **unintended externalities** of environmental regulations **along the supply chain** through the *NOx Budget Program (NBP)*
  - How non-NBP-regulated energy-consuming manufacturers' **emission policy** responds to the increase in their electricity price induced by *NBP*?

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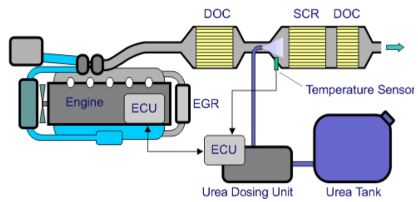
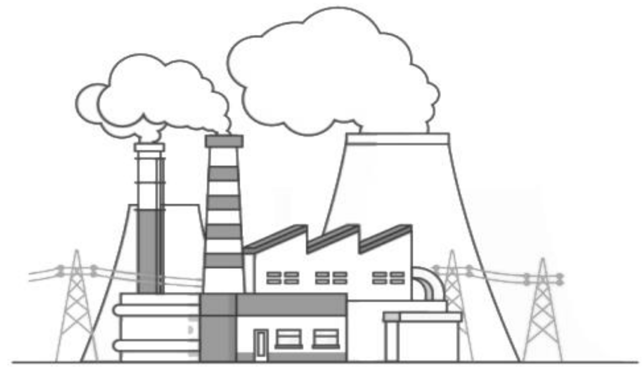
Passing Through High Compliance Costs Downstream

Compliance
Cost ↑

NOx↓



NOx
Budget **P**rogram
(NBP)

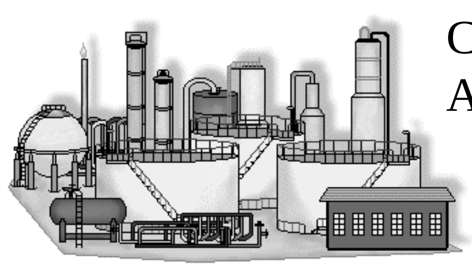


"*Energy Supplier*"
Utilities

Input Production
Cost ↑

Pass Through

Electricity
Price↑



"*Energy Consumers*"
Manufacturers

Costly
Abatement ↓

Harmful
Chemicals ↑

Local air
quality ↓

- **NBP regulates power sources**
  - Reduced NOx emissions in the regulated areas, affecting >2500 power sources.
- **Costly NBP compliance** for regulated power sources (Fowlie, *AER 2010*)
  - The aggregate NBP compliance costs is $1.1 billion/yr (Deschênes et al., *AER 2017*)
- **High pass-through** of the compliance costs **to manufacturers** (Fowlie, *AER 2010*)
  - We show energy prices charged to manufacturers ↑>7% in states participant NBP from 2004
  - Similar to Curtis (*REStat 2018*) and Dang et al. (*2022*)

➢ Energy-intensive manufacturing firms thus experience a **production cost** shock.

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Energy-Consuming Manufacturers' Emission Responses

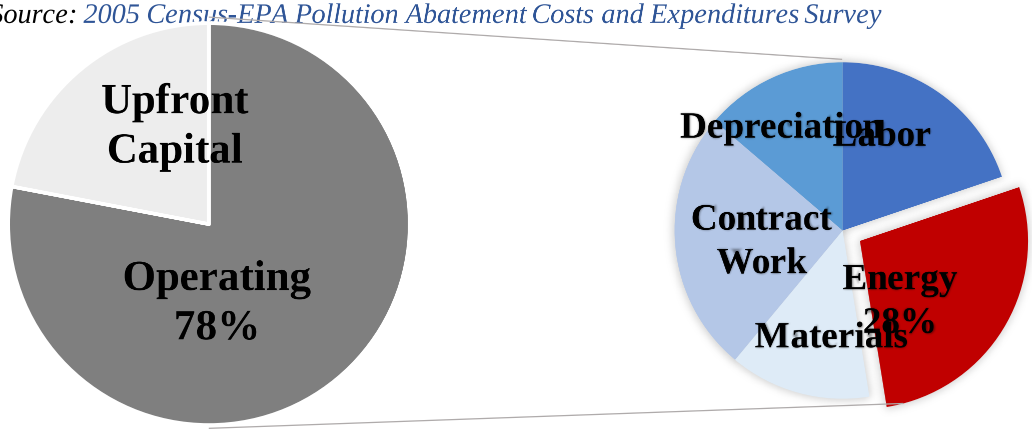
- Electricity prices ↑, pollution abatement cost ↑
  - **Energy costs** ~ 28% of abatement operating costs
  - Other abatement components likely become less affordable.
- Manufacturers may have some slacks to increase emissions without triggering EPA enforcement
  - EPA condition its enforcement intensity on county's nonattainment status
  - Some manufacturers may have left some safety margin (in anticipation of productions↑, enforcement↑, physical deterioration↓)

Ways to Cut Abatement Costs (e.g., Becker, 2005; Fowlie, 2010)

- Directly shut down some abatement facilities (to save energy, reagents consumption)
- Adopt less capital intensive but less efficient abatement options
- Retrench environmental engineering labor
- Cut contracted services
- Delay the replacement of deprecated abatement devices

Total Abatement Cost

Source: 2005 Census-EPA Pollution Abatement Costs and Expenditures Survey



Preview of the findings

- Non-NBP-regulated energy-consuming manufacturing plants located in NBP states emit more **harmful chemicals** into the air.
  - Channel: changes in costly abatement activities
  - Cross-sectional analyses: concentrated in constrained myopic manufacturers
    - The roles of economic constraints
    - The roles of managerial short-term incentives
  - Tradeoff between abatement cost and expected EPA penalty
  - Worsened air quality near the manufacturing plants.
    - Tend to be underprivileged communities.

Contributions

- Extend the literature on **substitution** effects of environmental regulations
  - **Direct effects** on regulated firms' internal substitution:
    - Cross-media:
      - Greenstone (*AER 2003*), Gibson (*REStat 2019*)
    - Cross-spatial:
      - Domestic: Gibson (*REStat 2019*), Bartram, Hou, and Kim (*JFE 2022*)
      - Foreign: Ben-David, Jang, Kleimeier, and Viehs (*2021*), Dai, Duan, Liang and Ng (*2022*)
  - **Indirect effects** on unregulated firms:
    - Lending substitution - Laeven and Popov (*2022*)
    - Conservative capital structure - Dang, Gao, and Yu (*WP 2022*)

    ✓We focus on emissions spillover along the supply chain

    ✓We examine the toxicity of emissions and find harmful chemical ↑

✓Help policymakers better design future regulations to reduce the negative externalities

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Contributions

- Extend literature on the **substitution effects of environmental regulations:**
  - Emissions spillover along the supply chain
  - Emissions of manufacturers unregulated by the environmental regulation
- Provide a better understanding of the **costs and benefits** of the NBP
  - Emission of harmful chemicals
  - Environmental consequences of the affected neighborhood
- NBP could have been more effective in achieving its goal in the environment and human health.

NOx Budget Program (NBP)

- The NBP was created with the purpose of limiting the environmental harm that **NOx emitters** could impose on downwind states.

Multiple legal challenges by **Upwind** states

2004 Upwind States start NBP

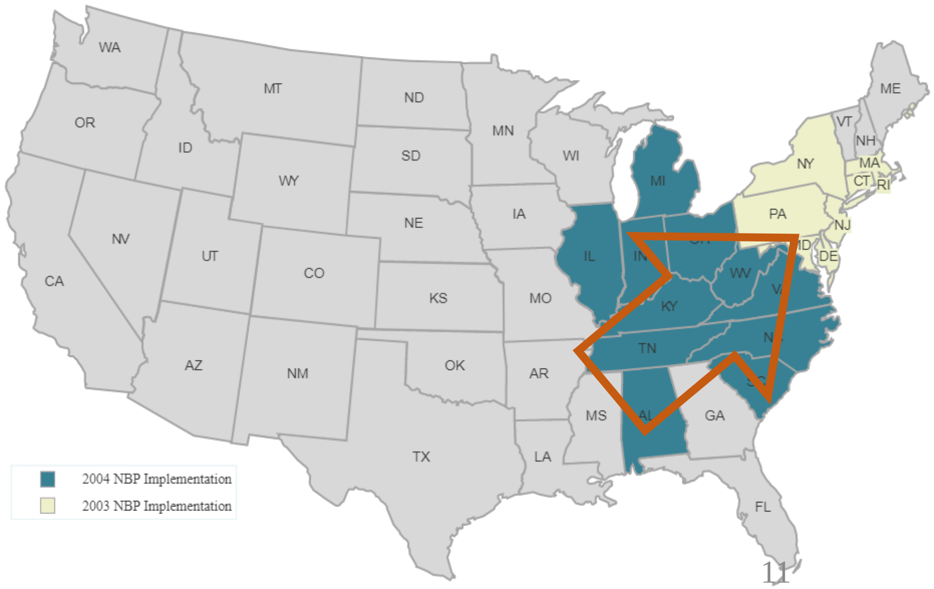
2008 End of NBP

1999-2002 **Downwind** States run the *initial* version of NBP

1997 **Downwind** States petition EPA

2003 **Downwind** States start NBP

- The 11 upwind states did not begin participation until **2004**. And it was **not fully anticipated** due to legal battles.



Data

- **EPA's Toxic Release Inventory (TRI) database**
  - Extensively used by economists
    - Greenstone (AER 2003), Currie (AER 2011) and Gibson (REStat 2019), etc.
    - Akey and Appel (JF 2021), Heitz, Wang, and Wang (MS 2021), Xu and Kim (RFS 2022), etc.
  - Self-reported by plants, several mechanisms to ensure the data quality:
    - Constitute criminal offenses and result in civil and administrative penalties
    - Regular data quality checks
    - Onsite inspections

Data

- **EPA's Pollution Prevention (P2) database**
  - **Production Ratio**: Changes in the output or outcome of processes in which a chemical is involved.
    - If a chemical is used in car manufacturing, the ratio for year t: $\frac{\#CarsProduced_t}{\#CarsProduced_{t-1}}$
    - If a chemical is used to clean molds, the ratio for year t: $\frac{\#MoldsCleaned_t}{\#MoldsCleaned_{t-1}}$
    - If a chemical is used in multiple production processes, firms are required to report a weighted average
- **EPA's Integrated Risk Information System (IRIS)**
  - Information source on the toxicity of chemicals.
  - Link the IRIS database and the TRI database by standard chemical identifiers (i.e., Chemical Abstract Services (CAS) numbers)

Summary Statistics

Panel A. Plant-Chemical-Year-level variables

	Publicly Owned				Privately Owned			
Variable	**N**	**Mean**	**Median**	**SD**	**N**	**Mean**	**Median**	**SD**
Total Emissions (lb)	55,263	39,509	1,179	469,121	197,486	28,920	858	276,075
Harmful Chemical	55,263	0.524	1	0.499	197,486	0.534	1	0.499
Production Ratio	55,263	0.974	1	0.345	197,486	0.944	1	0.395
Operating Practice Abatement	55,263	0.085	0	0.326	197,486	0.076	0	0.308
Material & Process Abatement	55,263	0.073	0	0.307	197,486	0.076	0	0.310

Panel B. Firm-Year-level variables (for public firms)

Variable	**N**	**Mean**	**SD**	**p25**	**Median**	**p75**
log(Assets)	55,263	8.678	2.035	7.372	8.36	9.659
ROA	55,263	0.050	0.074	0.014	0.045	0.083
Leverage	55,263	0.281	0.164	0.164	0.254	0.376
Market-to-Book	55,263	1.604	0.77	1.106	1.382	1.798
Tangibility	55,263	0.746	0.308	0.528	0.726	0.961

Research Design

- Take advantage of the **geographic, time, and industry** heterogeneity and conduct DDD tests at **Plant-Chemical-Year** for **non-NBP-regulated manufacturing plants:**

$$\log\left(\boldsymbol{TotalEmissions_{s,i,j,k,t}}\right) = \boldsymbol{\beta_1 NBP_{s,j}} \times \boldsymbol{Post_t} \times \boldsymbol{HighEnergy_j} + \beta_2 NBP_{s,j} \times Post_t + \beta_3 Post_t \times HighEnergy_j + \gamma ProductionRatio_{s,i,j,k,t} + \delta' Firm\ Control_{i,t-1} + Plant_j\ FE + Chemical_k \times Year_t\ FE + \epsilon_{s,i,j,k,t}$$

  - where s, i, j, k, and t denote a state, firm, plant, chemical, and year, respectively.
  - $\log(TotalEmissions_{s,i,j,k,t})$ is the natural log of total pounds of release for each chemical k from plant j of firm i that is located in state s in year t.
  - $NBP_{s,j}$ =1 for manufacturing plants located in the states that have NBP from 2004 to 2007, and zero for the plants that are located in a state not affected by the NBP.
  - $Post_t$ =1 for the years 2004 to 2007, and zero for the years 2000 to 2003.
  - $HighEnergy_j$ =1 if the plant's industry is among the top five energy consumption manufacturing industries *before the event*, and zero otherwise.
  - $ProductionRatio_{s,i,j,k,t}$ is the ratio of current-year to previous-year output at plant-chem level (enable us to hold Δ economic activities constant)
  - Firm level control: log(AT), ROA, Leverage, M/B, Tangibility.
  - Standard errors: clustered at plant levels (or state levels)

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Main Results: Effects of the NBP on Plant-Chemical-Year-Level Emissions

$$\log(\boldsymbol{TotalEmissions_{s,i,j,k,t}}) = \boldsymbol{\beta_1 NBP_{s,j} \times Post_t \times HighEnergy_j} + \beta_2 NBP_{s,j} \times Post_t + \beta_3 Post_t \times HighEnergy_j + \gamma ProductionRatio_{s,i,j,k,t} + \delta' Firm\ Control_{i,t-1} + Plant_j\ FE + Chemical_k \times Year_t\ FE + \epsilon_{s,i,j,k,t}$$

- $\boldsymbol{\beta_1}$:
  - The diff in the change in the total emissions **between high energy-consuming plants *and* low energy-consuming plants** around NBP implementation in the NBP regulated states relative to the control group.
- $\boldsymbol{\beta_1}+\boldsymbol{\beta_2}$:
  - The diff in the change in the total emissions of the **high energy-consuming manufacturing** around NBP implementation in the NBP regulated states relative to the control group.

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Dependent Variable:	*log(Total Emissions* $_{s,i,j,k,t}$*)*			
	(1)	(2)	(3)	(4)
$NBP_{s,j} \times Post_t \times HighEnergy_j\ (\beta_1)$	0.480***	0.310**		
	(3.546)	(2.288)		
$Post_t \times HighEnergy_j$	–0.098	–0.147*		
	(–1.094)	(–1.758)		
$NBP_{s,j} \times Post_t\ (\beta_2)$	–0.091	–0.092	0.018	–0.019
	(–1.469)	(–1.617)	(0.325)	(–0.364)
$ProductionRatio_{s,i,j,k,t}$	0.335***	0.242***	0.333***	0.241***
	(7.301)	(5.836)	(7.226)	(5.770)
$log(Assets_{i,t-1})$	0.106	0.127*	0.101	0.105
	(1.432)	(1.924)	(1.296)	(1.545)
$ROA_{i,t-1}$	0.613***	0.731***	0.655***	0.716***
	(3.100)	(3.529)	(3.327)	(3.480)
$Leverage_{i,t-1}$	–0.004	–0.071	0.013	–0.040
	(–0.022)	(–0.420)	(0.070)	(–0.234)
$Market\text{-}to\text{-}Book_{i,t-1}$	0.062*	0.071**	0.062*	0.067**
	(1.878)	(2.131)	(1.869)	(2.011)
$Tangibility_{i,t-1}$	0.151	0.024	0.177	0.022
	(0.836)	(0.152)	(0.964)	(0.136)
Plant FE	Y	Y	Y	Y
Year FE	Y	N	Y	N
Chemical-by-Year FE	N	Y	N	Y
Observations	55,263	54,846	55,263	54,846
Adjusted R-squared	0.363	0.671	0.363	0.671
$(\beta_1 + \beta_2)$	0.389	0.217	/	/
p-value of $(\beta_1 + \beta_2)$	0.001***	0.073*	/	/

- $\boldsymbol{\beta_1}$ → **high and low energy-consuming** plants **respond differently** to the NBP implementation in their emissions.
- $\boldsymbol{\beta_1 + \beta_2}$ → the total emissions of the **high energy-consuming** manufacturing plants ↑ **21.8%** around NBP implementation relative to the change in the control group

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Parallel Trend of NBP Effects on Total Emissions

Dependent Variable:	**log(*Total Emissions*$_{s,i,j,k,t}$)**			
	High Energy		*Low Energy*	
	(1)	(2)	(3)	(4)
NBP × Year (-4)	0.097	0.128	0.044	0.045
	(0.566)	(0.694)	(0.487)	(0.537)
NBP × Year (-3)	–0.050	–0.085	0.011	0.040
	(–0.350)	(–0.524)	(0.158)	(0.585)
NBP × Year (-2)	–0.129	–0.008	0.004	0.009
	(–1.241)	(–0.065)	(0.064)	(0.144)
NBP × Year (0)	0.192	0.012	–0.055	–0.067
	(1.502)	(0.101)	(–0.933)	(–1.232)
NBP × Year (1)	0.354***	0.245*	–0.030	–0.026
	(2.850)	(1.964)	(–0.406)	(–0.386)
NBP × Year (2)	0.465***	0.299*	–0.096	–0.096
	(3.064)	(1.878)	(–1.168)	(–1.272)
NBP × Year (3)	0.254	0.048	–0.090	–0.098
	(1.384)	(0.257)	(–0.925)	(–1.103)
ProductionRatio	0.383***	0.231***	0.320***	0.246***
	(4.201)	(2.821)	(6.161)	(5.071)
Firm Controls	Y	Y	Y	Y
Plant FE & Year FE	Y	Y	Y	Y
Chemical-by-Year FE	N	Y	N	Y
Observations	14,398	14,231	40,855	40,389
Adjusted R-squared	0.288	0.717	0.394	0.675

- **The result that we show in the baseline analysis is likely causal.**

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Evidence on the Channels Underlying the Observed Increases

- **For the form of emissions:**
  - Increase in emissions are concentrated in the released into **air**, rather than into water or ground
    - According to EPA survey, air emission abatements are more ***costly***
- **For the human health toxicity:**
  - Increase in emissions are concentrated in **harmful chemicals**, rather than those non-harmful to human health
    - According to EPA, harmful chemical abatements are more **energy-consuming and costly**
- **The effects of NBP on pollution abatements activities**
  - Reduce abatements related to the **material and process modification** rather than those related to operating practices
    - According to EPA, material and process improvements related abatements generally need **more effort and higher costs**

➢**Change in costly abatement** seems to be a plausible channel

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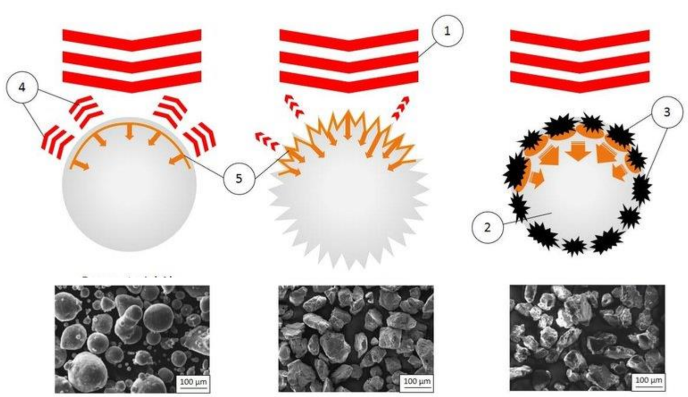
Material & Process Abatement

- Modifying a production process to produce less waste
- Using non-toxic or less toxic chemicals as cleaners, degreasers and other maintenance chemicals



Operating Practice Abatement

- Improving maintenance scheduling, record keeping
- Practices that enhance operator expertise and housekeeping measures that minimize waste

The Effects of NBP's Implementation on Different Emissions

Dependent Variable:	*Air Emissions*$_{s,i,j,k,t}$		*Water Emissions*$_{s,i,j,k,t}$		*Ground Emissions*$_{s,i,j,k,t}$	
	(1)	(2)	(3)	(4)	(5)	(6)
$NBP_{s,j} \times Post_t \times HighEnergy_j$ (β_1)	0.333**	0.213*	0.067	0.031	–0.048	–0.040
	(2.492)	(1.690)	(0.862)	(0.409)	(–0.402)	(–0.353)
$NBP_{s,j} \times Post_t$ (β_2)	–0.003	–0.076	–0.081*	–0.039	–0.035	0.003
	(–0.044)	(–1.020)	(–1.865)	(–0.916)	(–0.707)	(0.059)
$Post_t \times HighEnergy_j$	0.116*	0.090*	–0.034	–0.025	–0.021	–0.001
	(1.878)	(1.751)	(–1.312)	(–0.959)	(–0.761)	(–0.035)
$ProductionRatio_{s,i,j,k,t}$	0.357***	0.260***	0.040*	0.026	0.002	–0.008
	(8.591)	(7.038)	(1.847)	(1.390)	(0.060)	(–0.279)
Firm Controls	Y	Y	Y	Y	Y	Y
Plant FE	Y	Y	Y	Y	Y	Y
Year FE	Y	N	Y	N	Y	N
Chemical-by-Year FE	N	Y	N	Y	N	Y
Observations	55,263	54,846	55,263	54,846	55,263	54,846
Adjusted R-squared	0.408	0.738	0.432	0.603	0.483	0.508
($\beta_1 + \beta_2$)	0.449	0.303	0.033	0.005	–0.069	–0.041
p-value of ($\beta_1 + \beta_2$)	0.000***	0.008***	0.652	0.941	0.555	0.712

The Effects of NBP's Implementation on Harmful Emissions

Dependent Variable:	*log(Total Emissions$_{s,i,j,k,t}$)*			
Split by pollutant's human health impact:	*Harmful Chemicals*		*Others*	
	(1)	(2)	(3)	(4)
$NBP_{s,j} \times Post_t \times HighEnergy_j$ (β_1)	0.564***	0.449**	0.368**	0.148
	(3.118)	(2.515)	(2.235)	(0.900)
$NBP_{s,j} \times Post_t$ (β_2)	–0.144	–0.209*	–0.097	–0.073
	(–1.347)	(–1.829)	(–0.833)	(–0.632)
$Post_t \times HighEnergy_j$	–0.119	–0.136*	–0.128	–0.088
	(–1.631)	(–1.918)	(–1.392)	(–1.019)
$ProductionRatio_{s,i,j,k,t}$	0.294***	0.253***	0.345***	0.234***
	(6.220)	(5.431)	(5.130)	(4.030)
Firm Controls	Y	Y	Y	Y
Plant FE	Y	Y	Y	Y
Year FE	Y	N	Y	N
Chemical-by-Year FE	N	Y	N	Y
Observations	28,907	28,684	26,233	26,038
Adjusted R-squared	0.459	0.585	0.410	0.727
($\beta_1 + \beta_2$)	0.444	0.313	0.240	0.061
p-value of ($\beta_1 + \beta_2$)	0.006***	0.049**	0.083*	0.671
Testing coefficient equality for $NBP \times Post \times HighEnergy$ (β_1):				
p-value for (1) vs. (3)	0.002***			
p-value for (2) vs. (4)	0.012**			

Channel: Cut Costly Pollution Abatement Activities

Dependent Variable:	*Material & Process Modification$_{i,j,k,s,t}$*		*Good Operating Practice$_{i,j,k,s,t}$*	
	(1)	(2)	(3)	(4)
$NBP_{s,j} \times Post_t \times HighEnergy_j$ (β_1)	–0.037**	–0.038*	–0.004	–0.006
	(–1.975)	(–1.958)	(–0.252)	(–0.337)
$NBP_{s,j} \times Post_t$ (β_2)	0.017	0.013	0.001	0.003
	(1.317)	(0.971)	(0.121)	(0.274)
$Post_t \times HighEnergy_j$	0.008	0.008	–0.000	–0.000
	(0.902)	(0.928)	(–0.015)	(–0.012)
$ProductionRatio_{s,i,j,k,t}$	–0.002	–0.002	0.002	0.001
	(–0.456)	(–0.556)	(0.545)	(0.329)
Firm Controls	Y	Y	Y	Y
Chemical-by-Year FE	Y	Y	Y	Y
Plant FE	Y	N	Y	N
Year FE	N	Y	N	Y
Observations	55,263	54,846	55,263	54,846
Adjusted R-squared	0.390	0.394	0.533	0.536
($\beta_1 + \beta_2$)	–0.029	–0.029	–0.004	–0.006
p-value of ($\beta_1 + \beta_2$)	0.083*	0.094*	0.765	0.695

- The increase of emission is **due to the decrease of costly abatement activities**

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Cross-Sectional Analysis

- **The Roles of Economic Constraints:**
  - Tighter financial constraints
  - Lower product market power
- **The Roles of Economic Incentives:**
  - High-powered executive incentives: delta and vega
  - Short-termism (high transient IOship)
  - Higher stock price sensitivities to earnings
  - Public listing status
- Overall, our results indicate that **constrained myopic** manufacturers cut corners by reducing costly abatements to absorb the NBP induced increase in energy input cost.

The Roles of Economic Constraints: Financial constraints and product market competition

Dependent Variable:	*log(Total Emissions$_{s,i,j,k,t}$)*			
Split by:	Financial constraints:		Product Pricing Power:	
	High Constraints	*Low Constraints*	*More Competitive Industries*	*Less Competitive Industries*
	(1)	(2)	(3)	(4)
$NBP_{s,j} \times Post_t \times HighEnergy_j$ (β_1)	0.398**	0.134	0.347**	0.222
	(2.058)	(0.714)	(2.089)	(0.943)
$NBP_{s,j} \times Post_t$ (β_2)	0.001	–0.089	–0.101	–0.026
	(0.014)	(–1.203)	(–1.350)	(–0.304)
$Post_t \times HighEnergy_j$	–0.206	0.022	–0.109	–0.162
	(–1.626)	(0.190)	(–1.157)	(–0.924)
$ProductionRatio_{s,i,j,k,t}$	0.301***	0.212***	0.245***	0.246***
	(4.626)	(4.007)	(4.504)	(3.876)
Firm Controls	Y	Y	Y	Y
Plant FE	Y	Y	Y	Y
Chemical-by-Year FE	Y	Y	Y	Y
Observations	21,740	32,769	31,578	21,950
Adjusted R-squared	0.677	0.683	0.693	0.666
$(\beta_1 + \beta_2)$	0.399	0.045	0.245	0.196
p-value of $(\beta_1 + \beta_2)$	0.018**	0.792	0.097*	0.372
Testing coefficient equality for $NBP \times Post \times HighEnergy$ (β_1):				
p-value for (1) vs. (2) or (3) vs. (4)	0.042**		0.037**	

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The Roles of Economic Incentives:
CEO compensation and shareholder short-termism

Panel A. Using Plants Owned by Public Firms

Dependent Variable:	***log(Total Emissions$_{s,i,j,k,t}$)***							
Split by:	Executives' pay-performance sensitivity:		Executives' pay-performance sensitivity:		Shareholder short-termism:		Earnings response coefficient:	
	High Delta	*Low Delta*	*High Vega*	*Low Vega*	*High Transient IO*	*Low Transient IO*	*High ERC*	*Low ERC*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$NBP_{s,j} \times Post_t \times HighEnergy_j$ (β_1)	0.563***	0.140	0.842***	–0.071	0.449**	0.339	0.482**	0.183
	(2.806)	(0.566)	(3.215)	(–0.354)	(2.205)	(1.591)	(2.234)	(0.942)
$NBP_{s,j} \times Post_t$ (β_2)	–0.093	–0.055	–0.108	0.078	–0.094	–0.046	–0.092	–0.065
	(–1.214)	(–0.522)	(–1.367)	(0.838)	(–1.038)	(–0.587)	(–1.071)	(–0.857)
$Post_t \times HighEnergy_j$	–0.211**	0.000	–0.205*	0.064	–0.056	–0.267**	–0.165	–0.131
	(–2.020)	(0.001)	(–1.753)	(0.409)	(–0.441)	(–2.228)	(–1.396)	(–0.907)
$ProductionRatio_{s,i,j,k,t}$	0.261***	0.311***	0.284***	0.306***	0.294***	0.252***	0.169***	0.323***
	(4.451)	(3.933)	(4.886)	(4.002)	(4.561)	(4.108)	(2.839)	(5.707)
Firm Controls	Y	Y	Y	Y	Y	Y	Y	Y
Plant FE	Y	Y	Y	Y	Y	Y	Y	Y
Chemical-by-Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Observations	28,480	13,756	26,772	15,842	19,188	24,786	27,601	24,863
Adjusted R-squared	0.657	0.711	0.660	0.703	0.699	0.662	0.668	0.691
($\beta_1 + \beta_2$)	0.471	0.085	0.734	0.007	0.355	0.293	0.390	0.118
p-value of ($\beta_1 + \beta_2$)	0.011**	0.707	0.003***	0.968	0.052*	0.143	0.044**	0.513
Testing coefficient equality for $NBP \times Post \times HighEnergy$ (β_1):								
p-value for (1) vs. (2) or (3) vs. (4)	0.005***		0.001***		0.028**		0.023**	

The Roles of Economic Incentives: Public listing status

Panel B. Placebo Test Using Plants Owned by Private Firms

Dependent Variable:	$log(Total\ Emissions_{s,i,j,k,t})$			
	(1)	(2)	(3)	(4)
$NBP_{s,j} \times Post_t \times HighEnergy_j$ (β_1)	0.004	0.023	–0.025	0.013
	(0.048)	(0.335)	(–0.303)	(0.191)
$NBP_{s,j} \times Post_t$ (β_2)	–0.078**	–0.070**	–0.058	–0.050
	(–2.101)	(–2.055)	(–1.543)	(–1.437)
$Post_t \times HighEnergy_j$	–0.095*	–0.071	–0.092	–0.077
	(–1.713)	(–1.460)	(–1.598)	(–1.580)
$ProductionRatio_{s,i,j,k,t}$			0.460***	0.301***
			(19.329)	(16.720)
Plant FE	Y	Y	Y	Y
Year FE	Y	N	Y	N
Chemical-by-Year FE	N	Y	N	Y
Observations	197,486	196,866	188,557	187,955
Adjusted R-squared	0.442	0.705	0.440	0.705
$(\beta_1 + \beta_2)$	–0.074	–0.047	–0.083	–0.037
p-value of $(\beta_1 + \beta_2)$	0.290	0.413	0.240	0.528

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Tradeoff between Abatement Costs and Expected EPA Penalty

- **Whether the expected regulation stringency would shape emission responses**
  - Utilize the EPA Greenbook data: county level regulation stringency
    - manufacturers located in a county that has attainment status are subject to lower EPA regulation stringency
  - ➢ Only choose to cut corners in emissions when they perceive the potential EPA enforcement risk is limited.

- **Whether the plants involved in an enforcement action**
  - Utilize the EPA ECHO data: plant level EPA enforcement outcomes
  - ➢ Do not experience a higher incidence of being fined by EPA after the NBP

Emissions and the Potential Enforcement Risk

- Being labelled as a nonattainment county triggers air quality planning and control requirements that set out corrective actions to reduce toxic releases without regard to cost (Becker and Henderson, 2000; Greenstone, 2002; Walker, 2013).

Dependent Variable:	***log(Total Emissions*** $_{s,i,j,k,t}$***)***	
Split by expected monitoring and enforcement intensity:	*Attainment Counties (Low Enforcement Intensity)*	*Nonattainment Counties (High Enforcement Intensity)*
	(1)	(2)
$NBP_{s,j} \times Post_t \times HighEnergy_j$ (β_1)	0.415***	0.025
	(2.668)	(0.097)
$NBP_{s,j} \times Post_t$ (β_2)	–0.128**	0.127
	(–2.009)	(0.962)
$Post_t \times HighEnergy_j$	–0.285***	0.257
	(–2.970)	(1.376)
$ProductionRatio_{s,i,j,k,t}$	0.253***	0.204**
	(5.382)	(2.357)
Firm Controls	Y	Y
Plant FE	Y	Y
Year FE	Y	N
Chemical-by-Year FE	N	Y
Observations	43,232	11,341
Adjusted R-squared	0.673	0.698
$(\beta_1 + \beta_2)$	0.287	0.153
p-value of $(\beta_1 + \beta_2)$	0.042**	0.502
Testing coefficient equality for $NBP \times Post \times HighEnergy$ (β_1):		
p-value for (1) vs. (2)	0.924	

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Emissions and the Potential Enforcement Risk

- According to the EPA ECHO database, among our sample plants, 1.7% of plants have been fined by EPA.
- Since in the majority of cases, the database does not provide information on the specific type of TRI-listed chemicals involved in a violation, we can only estimate regressions at the plant-year-level level in the following test.

Panel B. Ex-post EPA Enforcement

Dependent Variable:	**Has EPA Fine $_{j,t}$ (0/1)**	
	(1)	(2)
NBP × Post × HighEnergy (β_1)	–0.010	–0.009
	(–0.732)	(–0.652)
NBP × Post (β_2)	0.008*	0.008*
	(1.744)	(1.743)
Post × HighEnergy	0.009	0.009
	(0.823)	(0.781)
Firm Controls	Y	Y
Plant FE	Y	Y
Year FE	Y	Y
Observations	15,171	15,107
Adjusted R-squared	0.016	0.017
p-value of $(\beta_1 + \beta_2)$	0.857	0.920

➢ have **carefully considered the tradeoff** between more emissions and expected enforcement cost

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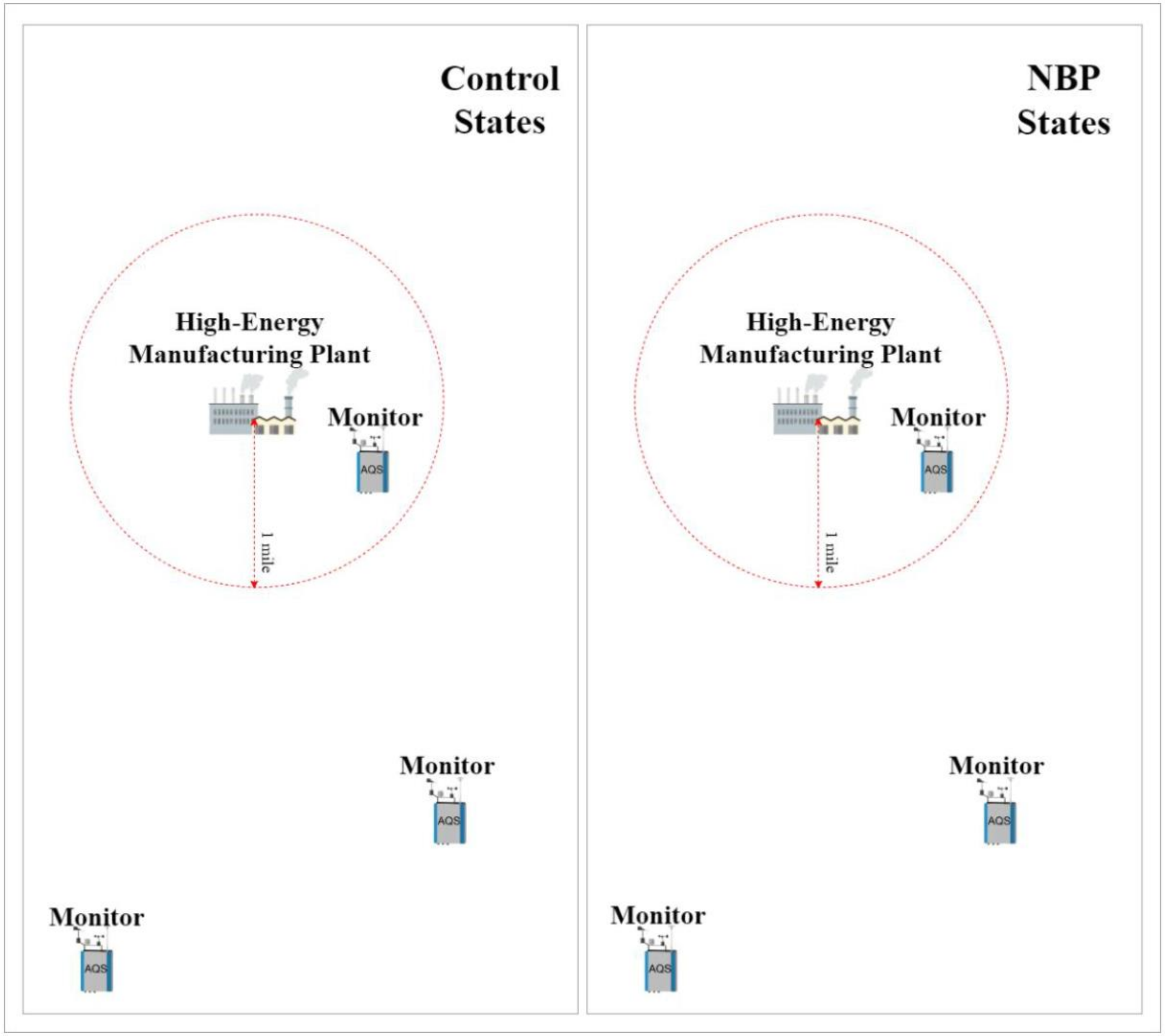
Local air quality near the non-NBP-regulated energy-consuming manufacturing plants



Local air quality near the non-NBP-regulated energy-consuming manufacturing plants

Dependent Variable:	*log*(**Daily Air Quality Reading$_{s,j,k,m,t}$**)		
Distance from a plant:	<=1 mile	<=5 miles	<=10 miles
	(1)	(2)	(3)
$NBP_{s,j} \times Post_t \times HighEnergy_j$ (β_1)	0.410**	0.041	0.018
	(2.041)	(0.948)	(0.779)
$NBP_{s,j} \times Post_t$ (β_2)	0.004	–0.009	0.024
	(0.041)	(–0.246)	(0.766)
$Post_t \times HighEnergy_j$	–0.357**	–0.038	–0.022
	(–2.269)	(–1.406)	(–1.602)
Weather Controls	Y	Y	Y
Chemical-by-Year FE	Y	Y	Y
Plant-Monitor Pair FE	Y	Y	Y
Observations	16,554	213,202	553,609
Adjusted R-squared	0.937	0.944	0.943
$(\beta_1 + \beta_2)$	0.414	0.032	0.042
p-value of $(\beta_1 + \beta_2)$	0.002***	0.579	0.319

Local community profiles near the non-NBP-regulated energy-consuming manufacturing plants

Dependent Variable:	*log(Income)*	*PovertyRate*	*log(Rent)*	*BlackRatio*	*Bachelor*	*SingleMom*
	(1)	(2)	(3)	(4)	(5)	(6)
Distance<=1 mile	–0.194***	0.083***	–0.072***	0.088**	–0.093***	0.049***
	(–4.803)	(4.305)	(–2.747)	(2.384)	(–5.649)	(3.494)
1 mile<Distance<=5 miles	–0.097***	0.047***	–0.067***	0.081**	–0.049**	0.031***
	(–4.755)	(3.900)	(–3.323)	(2.194)	(–2.471)	(2.859)
Plant FE	Y	Y	Y	Y	Y	Y
Observations	8,362	8,372	8,453	8,400	8,369	8,363
Adjusted R-squared	0.154	0.153	0.276	0.244	0.225	0.080

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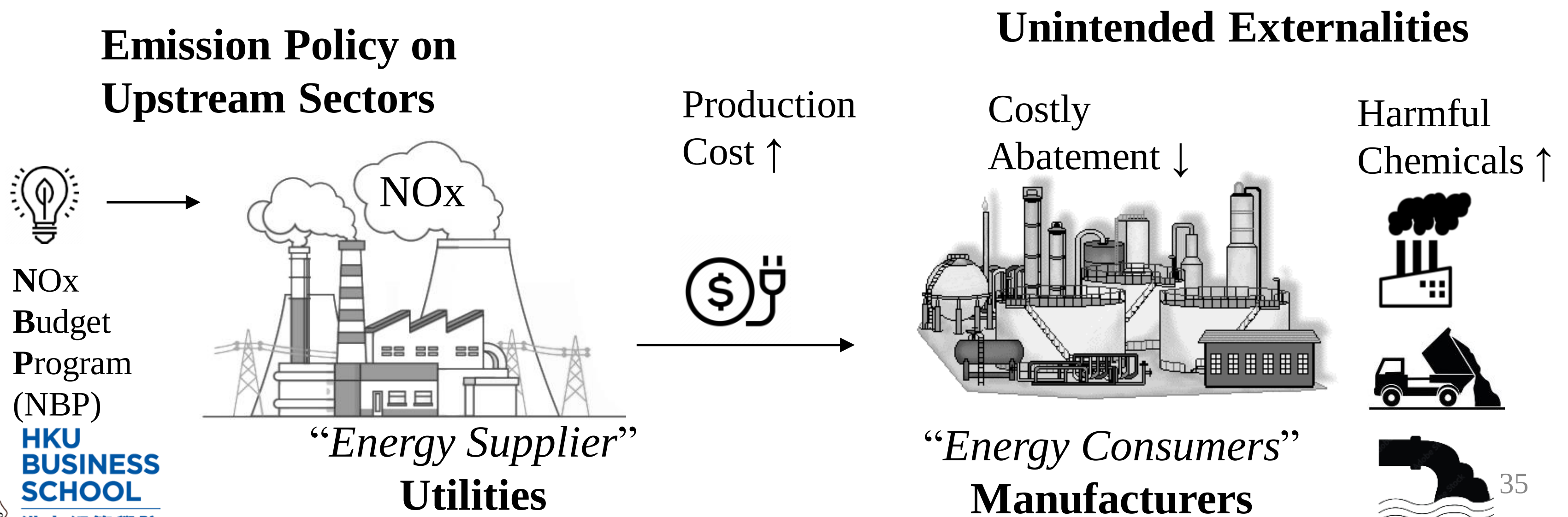
Other Tests and Robustness Checks

- ✓Verify the effects of the NBP on industrial electricity prices
- ✓Robustness by using different clustering levels
- ✓Robustness by using a balanced panel
- ✓Robustness by using a different treatment groups
- ✓Robustness by using alternative energy intensity measures
- ✓Examine the effects of the NBP on changes in production activities

Conclusion

- Document the **unintended emission spillover** *to* energy-intensive manufacturing plants that are not regulated by NBP.
  - High energy manufacturers emit more harmful chemicals after implementation
  - *Constrained myopic* manufacturers cut corners by reducing costly abatements to absorb the NBP induced increase in energy input cost.
- Without such negative externality, the NBP **can be even more effective** in improving the environment and human health.



Thank you!

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NBP Implementation and Industrial Electricity Prices

- *Industrial Electricity Price* is the average electricity price for industrial customers at the utility-year level, based on the Energy Information Administration (EIA).
- Following *Curtis (2018)*, we interact the average annual prices of three types of fuels (i.e., coal, oil, and natural gas represented by the variable *CoalPrice*, *OilPrice*, and *GasPrice*, respectively) with the corresponding percent of electricity derived from each type of fuel in each region.
- Observations are weighted by their 1999 revenue to ensure that the utilities with little or no electricity sales do not drive the results. Dollar values are expressed in the year 2000 dollars. Robust standard errors clustered at the plant level are reported in parentheses.

Dependent Variable:	log(*Industrial Electricity Price*)	
	(1)	(2)
NBP × POST	0.074**	0.072**
	(2.022)	(1.996)
Coal% × CoalPrice	3.639**	4.592***
	(2.510)	(5.007)
Oil% × OilPrice	2.857**	2.447**
	(2.164)	(2.186)
Gas% × GasPrice	5.290	8.459*
	(0.780)	(1.800)
East/West Trend	Y	Y
Year FE	Y	Y
State FE	Y	N
Utility FE	N	Y
Observations	11,594	11,530
Adjusted R-squared	0.539	0.821

Robustness:

	log(*Total Emissions*)			
	(1)	(2)	(3)	(4)
NBP×POST×EnergyIntensityQ4	0.466***	0.344**	0.455***	0.339**
	(2.904)	(2.156)	(2.828)	(2.125)
NBP×POST×EnergyIntensityQ3	-0.037	0.027	-0.121	-0.040
	(-0.240)	(0.181)	(-0.775)	(-0.273)
NBP×POST×EnergyIntensityQ2	-0.017	0.081	0.029	0.102
	(-0.117)	(0.627)	(0.204)	(0.793)
POST×EnergyIntensityQ4	-0.100	-0.141	-0.078	-0.121
	(-0.880)	(-1.338)	(-0.670)	(-1.128)
POST×EnergyIntensityQ3	-0.046	-0.044	0.034	0.015
	(-0.409)	(-0.403)	(0.294)	(0.138)
POST×EnergyIntensityQ2	0.025	0.053	0.023	0.066
	(0.232)	(0.545)	(0.211)	(0.664)
NBP×POST	-0.099	-0.158	-0.067	-0.121
	(-0.905)	(-1.519)	(-0.611)	(-1.162)
ProductionRatio			0.334***	0.242***
			(7.311)	(5.853)
Full Control	Y	Y	Y	Y
Plant FE	Y	Y	Y	Y
Year FE	Y	N	Y	N
Chemical-Year	N	Y	N	Y
Observations	57,099	56,680	55,263	54,846
Adjusted R-squared	0.367	0.670	0.363	0.671

Validity Test on Production Ratio

	Production Ratio	
	(1)	(2)
$NBP \times Post \times HighEnergy(\beta_1)$	-0.025	-0.027
	(-0.601)	(-0.685)
$NBP \times Post(\beta_2)$	-0.014	-0.014
	(-0.951)	(-0.924)
$Post \times HighEnergy$	0.009	0.007
	(0.318)	(0.232)
Full Control	Y	Y
Plant FE	Y	Y
Year FE	Y	N
Chemical-Year	N	Y
Observations	55,263	54,846
Adjusted R-squared	0.219	0.225
$(\beta_1 + \beta_2)$	-0.039	-0.041
p-value of $(\beta_1 + \beta_2)$	0.314	0.276

Production Ratio: changes in the output or outcome of processes in which a chemical is involved.

Eg: If a chemical is used in the manufacturing of refrigerators, the production ratio for year t is given by $\frac{\#RefrigeratorsProduced_t}{\#RefrigeratorsProduced_{t-1}}$

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