

Environmental Regulation and Industrial Performance: Evidence from China

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ABCDE Conference
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Motivations

The New York Times

Sinosphere

Dispatches From China

DECEMBER 5, 2013, 7:33 AM

Air Pollution Shrouds Eastern China

By *AUSTIN RAMZY*

Eastern China is suffering from some of the most severe air pollution in recent memory, forcing schools to cancel classes in the city of Nanjing and shrouding Shanghai's famous skyline in an acrid haze.

Nanjing called off classes for all of the city's kindergartens, elementary and middle schools Thursday, although schools remained open to watch over children who had no one to care for them during the day, the Nanjing-based Modern Express reported. In Shanghai, education officials told schools to call off outdoor activities due to the hazardous conditions.

Shanghai has reported air quality at levels deemed "heavily polluted" for much of the week. On Monday, the city's air quality index was over 301 — the threshold for "severely polluted," the most dangerous level according to China's national standards — for more than 10 hours, the official Shanghai Daily newspaper reported.

March 5, 2013, 7:37 PM

Kumamoto Residents Stay Indoors Amid China Pollution Fears

Article

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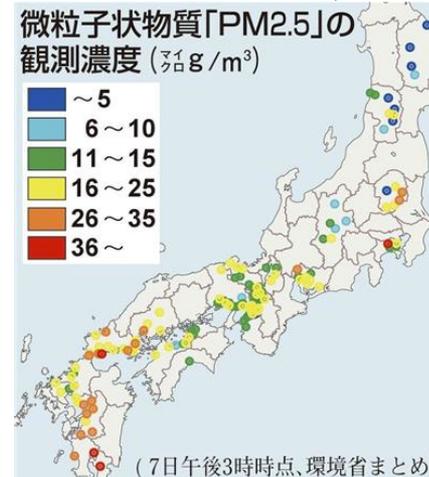
By Alexander Martin

Residents of Kumamoto Prefecture on Japan's southwestern island of Kyushu were asked to voluntarily stay in their homes Tuesday, after air pollution levels surpassed government safety standards.



The request was the first since [the environment ministry released new safety guidelines in February](#), and came as [Japan grows increasingly worried about toxic air pollution spilling over from China](#) and threatening Japanese coastal areas.

A spokesman for the prefecture said



Motivations



Motivations

Nov. 18, 2010

API: 243



Motivations

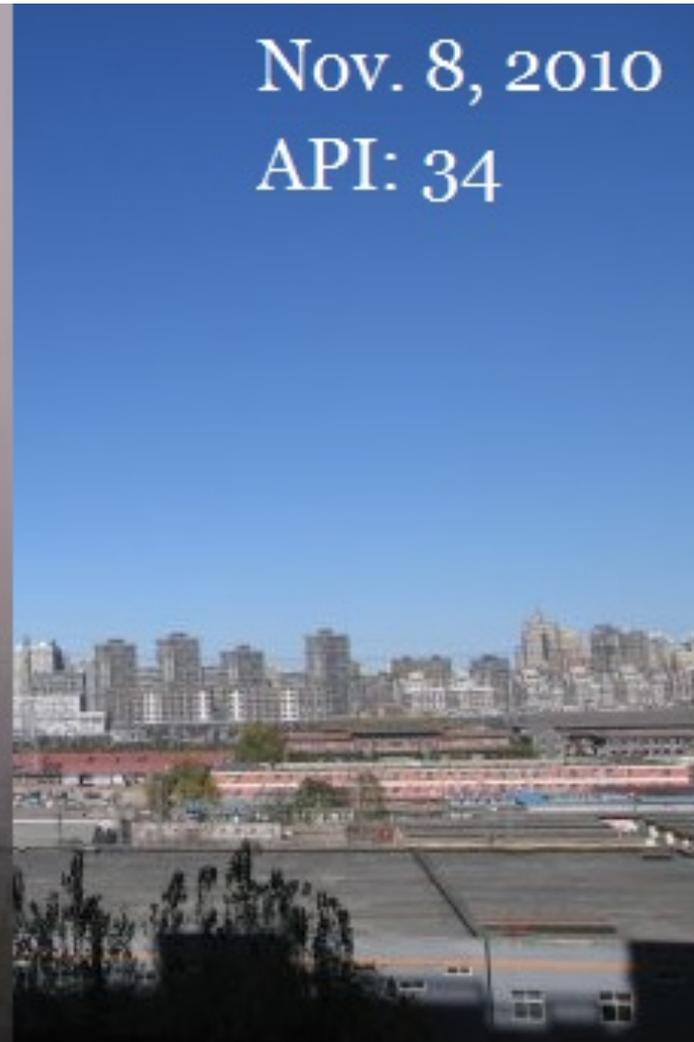
Nov. 18, 2010

API: 243



Nov. 8, 2010

API: 34



Motivations

- Environmental regulations are extremely contentious.

Education

(Currie et al. 2009)

Labor Supply

(Hanna and Oliva 2011)

Housing values

(Chay and Greenstone 2004)

Social Benefits

VS.

Infant mortality

(Chay and Greenstone 2003a, 2003b; Currie and Neidell 2005; Jayachandran 2009; Tanaka 2015; Greenstone and Hanna 2012);

Motivations

- Environmental regulations are extremely contentious.

Education

(Currie et al. 2009)

Labor Supply

(Hanna and Oliva 2011)

Housing values

(Chay and Greenstone 2004)

Plant location

(Henderson 1996;
Becker and
Henderson 2000);

Employment

(Greenstone
2002)

Social Benefits

VS.

Private Costs

Infant mortality

(Chay and Greenstone 2003a, 2003b;
Currie and Neidell 2005; Jayachandran
2009; Tanaka 2015; Greenstone and
Hanna 2012);

TFP

(Greenstone,
List, Syverson
2012)

Inward and outward FDI

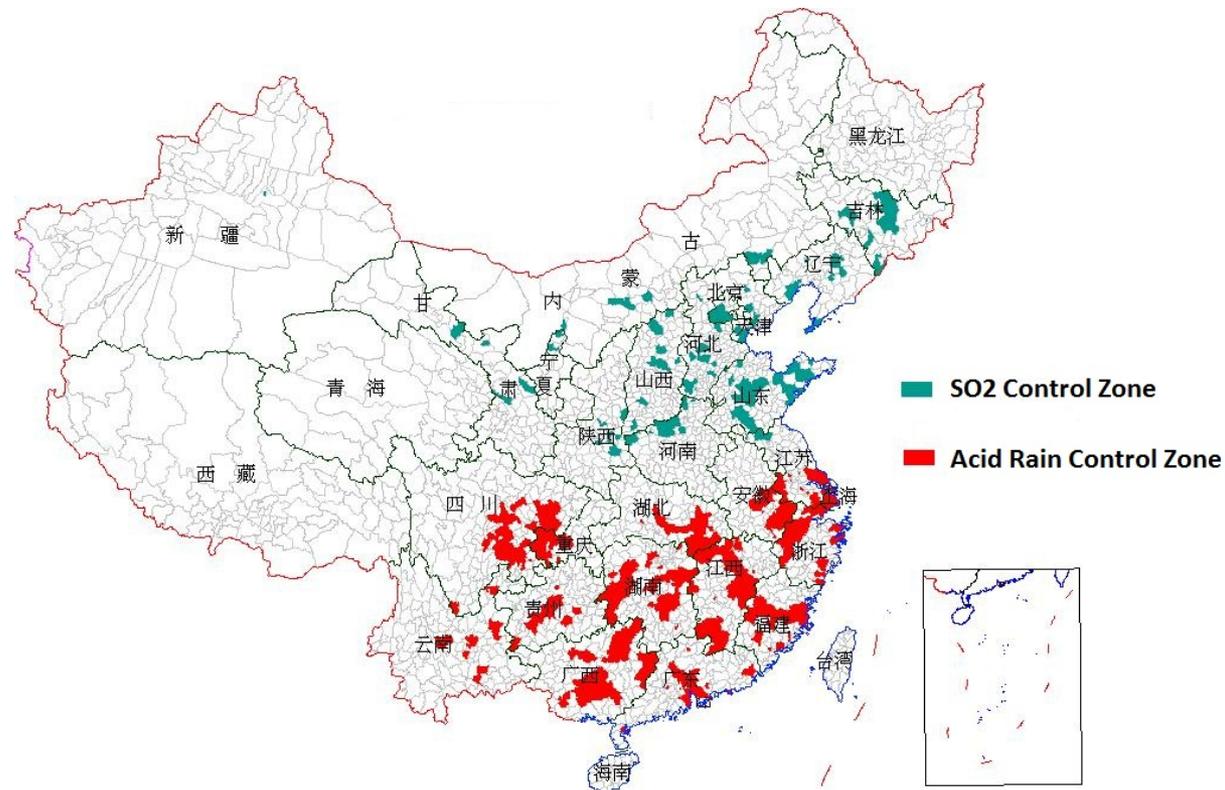
(Eskeland and Harrison
1997; Hanna 2010)

Our Study is...

- Objective:
 - Examine the effect of environmental regulations in China on industrial performance
- Significance:
 - Little evidence in developing countries
 - Positive effect on productivity
 - Induced innovation (Porter, 1991)
 - Resource misallocation (Hsieh and Klenow 2009)

Research Design

Two Control Zone Policy (1998)



Research Design

- SO₂ Pollution Control Zone
 - Annual average SO₂ $\geq 60 \mu\text{g}/\text{m}^3$
 - Daily average SO₂ $\geq 100 \mu\text{g}/\text{m}^3$
 - High SO₂ emissions
- Acid Rain Control Zone
 - pH for precipitation ≤ 4.5
 - Sulfate deposition is greater than the critical load
 - High SO₂ emissions

Research Design

Two Control Zone Policy (1998)

- Regulations
 - No new thermal power plants
 - Coal usage
 - Technology adoption
- Effectiveness
 - Hao et al. 2001; Yan et al. 2002; He, Huo, and Zhang 2002; UNEP 2009; Tanaka 2015

Data Sources

- Plant-level Information
 - The Annual Surveys of Industrial Production
 - From 1998 through 2005
 - Census of state-owned firms
 - Non-state-owned firms > RMB 5 million (\$600K) in revenues
 - > 250,000 firms and 33 industries in the power and manufacturing sectors
 - > 1 million observations at plant-by-year level

Econometric Modeling of Productivity

- The basic firm production function

$$y_{\text{fict}} = \alpha_1 l_{\text{fict}} + \alpha_2 k_{\text{fict}} + \alpha_3' X_{\text{fict}} + u_{\text{fict}}$$

- Y = Deflated sales
- L = Labor
- K = Capital
- X = A vector of controls that affect productivity
 - ln(Asset), Age, Ownership Type, Leverage, Capital Intensiveness

Econometric Modeling of Productivity

- Difference-in-Differences Strategy

$$y_{\text{fict}} = \beta_1 \text{Pollution}_i \times \text{TCZ}_c + \beta_2 \text{Energy}_i \times \text{TCZ}_c \\ + \alpha_1 l_{\text{fict}} + \alpha_2 k_{\text{fict}} + \alpha_3' X_{\text{fict}} + \eta_{ct} + \lambda_{it} + \varepsilon_{\text{fict}}$$

- Introducing Two Variations in Regulatory Stringency

- Across cities (within the industry)
- Across industries (within the city)

- Treatment Effect (β_1)

$$= E[(y_{P, \text{TCZ}} - y_{P, \text{nonTCZ}}) - (y_{NP, \text{TCZ}} - y_{NP, \text{nonTCZ}}) \mid \bullet]$$

$$= E[(y_{P, \text{TCZ}} - y_{NP, \text{TCZ}}) - (y_{P, \text{nonTCZ}} - y_{NP, \text{nonTCZ}}) \mid \bullet]$$

Main Effect

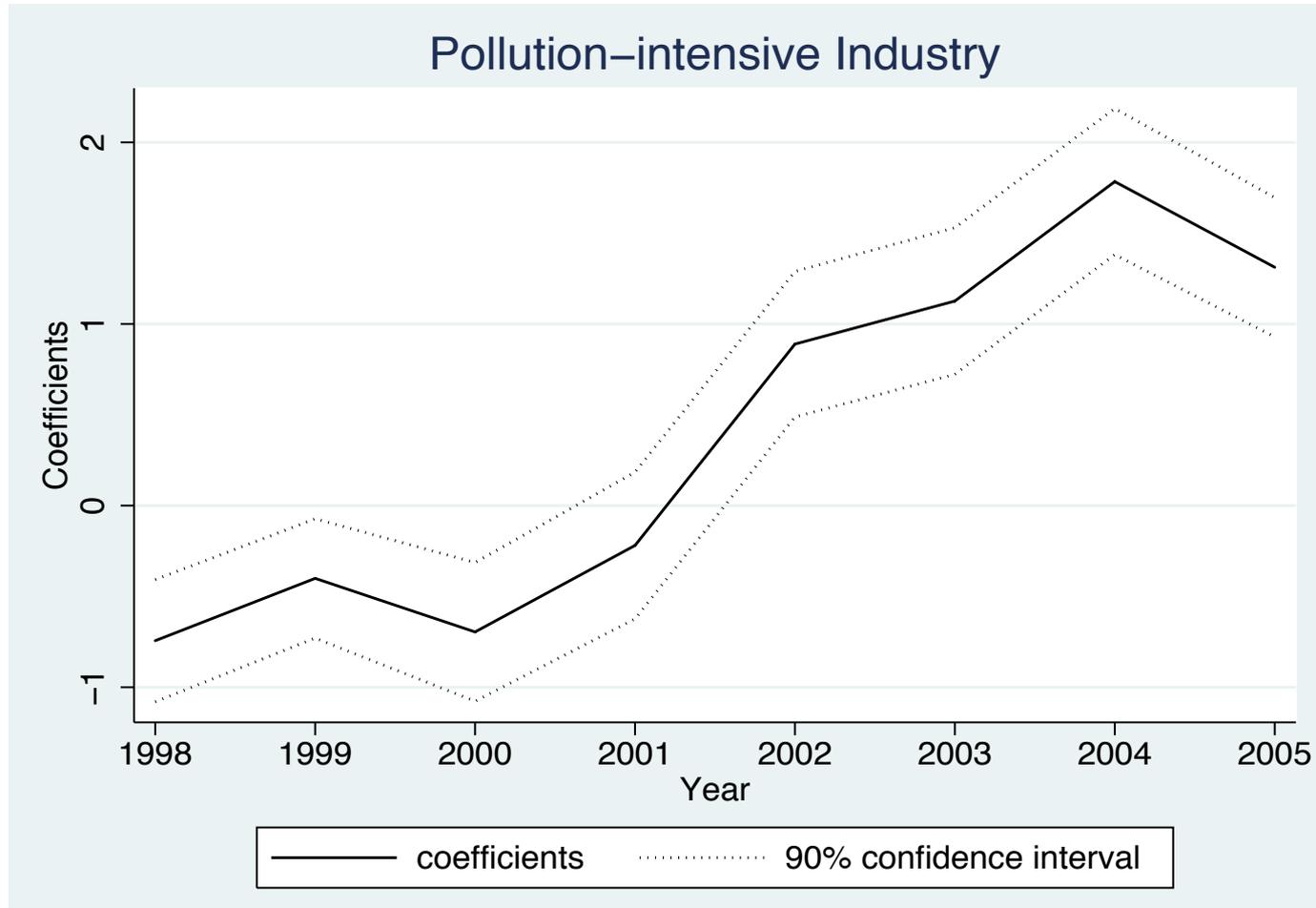
Table 2: Effect of TCZ Policy on Industrial Performance

	<i>Dependent var: Ln(Revenue)</i>				
	(1)	(2)	(3)	(4)	(5)
Coal Share × TCZ	1.353*** (0.173)	3.621*** (0.229)	2.761*** (0.246)	1.718*** (0.188)	1.318*** (0.213)
Energy Share × TCZ		-4.132*** (0.249)	-3.574*** (0.287)	-1.611*** (0.188)	-1.405*** (0.222)
Ln(Capital)				0.252*** (0.00204)	0.252*** (0.00250)
Ln(Labor)				0.598*** (0.00319)	0.594*** (0.00387)
Constant	10.65*** (0.0695)	10.66*** (0.0693)	12.82*** (1.947)	5.172*** (0.0579)	6.288*** (1.307)
Observations	1,107,642	1,107,642	842,792	1,093,171	831,734
R-squared	0.224	0.225	0.245	0.591	0.596
City-by-Industry controls	No	No	Yes	No	Yes
City-by-Year FE	Yes	Yes	Yes	Yes	Yes
Industry-by-Year FE	Yes	Yes	Yes	Yes	Yes

Notes: The table presents estimated coefficients based on equation (2). All specifications include city-year fixed effects and industry-year fixed effects. City-by-Industry controls include age, dummies for firm size, and dummies for ownership type. Robust standard errors clustered at city-industry level are reported in the parentheses.

*** p<0.01, ** p<0.05, * p<0.1

Dynamic Effect



Robustness using Alternative Measures

Table 3: Effect of TCZ Policy on Industrial Performance using Alternative Measures

	<i>Dependent variable</i>				
	Profits	ROA	ROE	ROCE	Net Income
	(1)	(2)	(3)	(4)	(5)
<i>Panel A: With no control</i>					
Coal Share ×					
TCZ	67,234*** (18,630)	0.0319 (0.0414)	0.0533 (0.108)	0.0157 (0.0880)	54,405*** (16,396)
<i>Panel B: With firm controls</i>					
Coal Share ×					
TCZ	48,208** (20,277)	0.0743*** (0.0219)	0.110** (0.0498)	0.0796* (0.0463)	36,013** (17,759)
<i>Panel C: With city-by-industry controls</i>					
Coal Share ×					
TCZ	59,026** (23,224)	0.0367 (0.0262)	0.220*** (0.0536)	0.212*** (0.0503)	42,616** (19,981)
<i>Panel D: With all controls</i>					
Coal Share ×					
TCZ	48,401** (24,148)	0.0534** (0.0256)	0.0941* (0.0549)	0.0438 (0.0528)	33,695 (21,049)

Effect on Firm Turnover and Selection Dynamics

- **Less firms entered** the market

Table 4: Effect on Firm Turnover and Selection Dynamics

Dep. Var.	Enter1	Enter2
Sample	All	All
	(1)	(2)
Coal Share \times TCZ	-0.0993*** (0.0307)	-0.0812*** (0.0275)
Firm controls	Yes	Yes
City-by-Industry controls	Yes	Yes
City-by-Year FE	Yes	Yes
Industry-by-Year FE	Yes	Yes

Effect on Firm Turnover and Selection Dynamics

- Less firms entered the market
- **More** firms **exited** the market

Table 4: Effect on Firm Turnover and Selection Dynamics

Dep. Var.	Enter1	Enter2	Exit	Exit
Sample	All	All	All	Incumbents
	(1)	(2)	(3)	(4)
Coal Share \times TCZ	-0.0993*** (0.0307)	-0.0812*** (0.0275)	0.0940*** (0.0246)	0.0713** (0.029)
Firm controls	Yes	Yes	Yes	Yes
City-by-Industry controls	Yes	Yes	Yes	Yes
City-by-Year FE	Yes	Yes	Yes	Yes
Industry-by-Year FE	Yes	Yes	Yes	Yes

Effect on Firm Turnover and Selection Dynamics

- Less firms entered the market
- More firms exited the market
- **Entrants** performed **better**

Table 4: Effect on Firm Turnover and Selection Dynamics

Dep. Var.	Enter1	Enter2	Exit	Exit	ln(Revenue)
Sample	All	All	All	Incumbents	Entrants
	(1)	(2)	(3)	(4)	(5)
Coal Share \times TCZ	-0.0993*** (0.0307)	-0.0812*** (0.0275)	0.0940*** (0.0246)	0.0713** (0.029)	1.643*** (0.254)
Firm controls	Yes	Yes	Yes	Yes	Yes
City-by-Industry controls	Yes	Yes	Yes	Yes	Yes
City-by-Year FE	Yes	Yes	Yes	Yes	Yes
Industry-by-Year FE	Yes	Yes	Yes	Yes	Yes

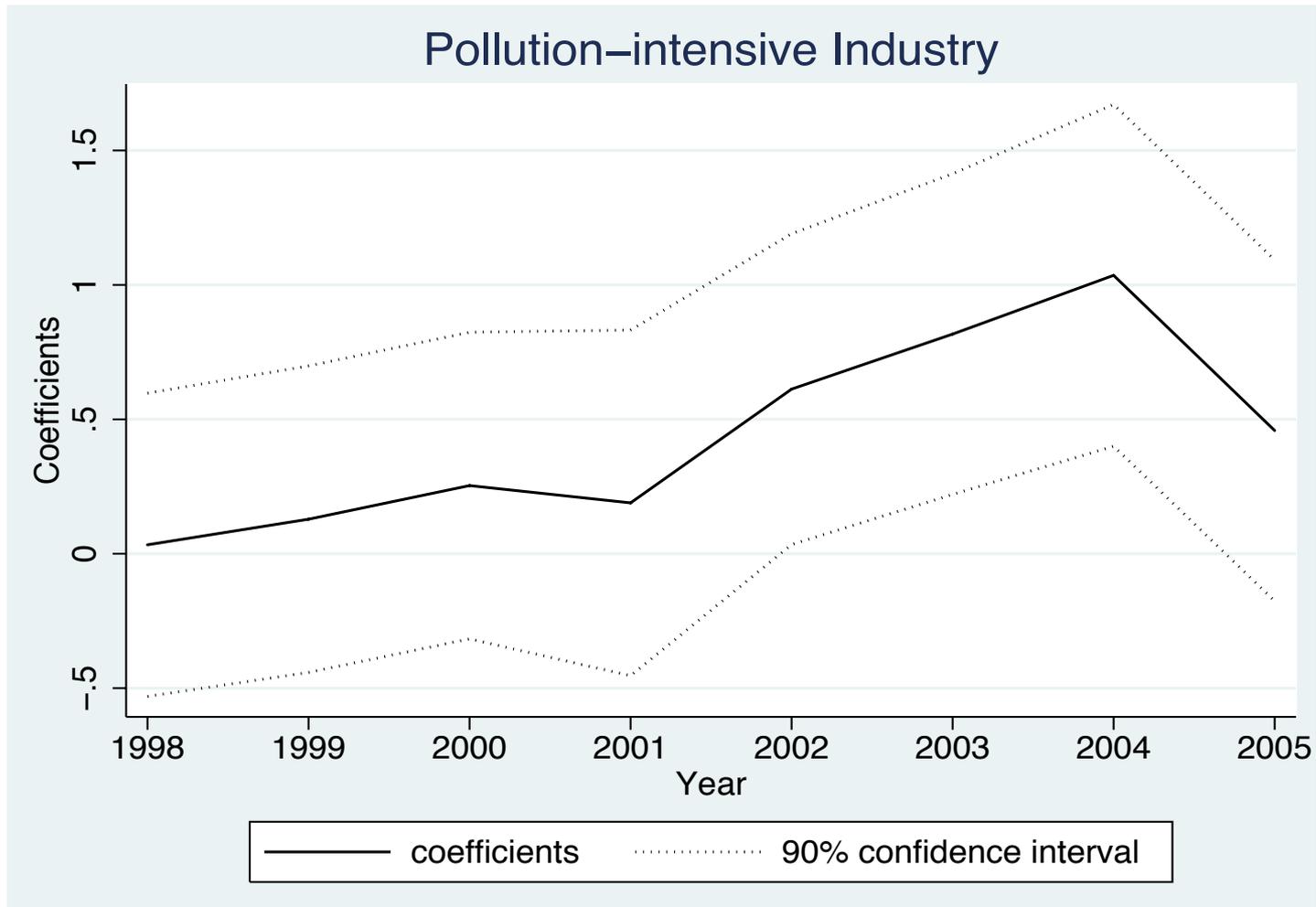
Effect on Firm Turnover and Selection Dynamics

- Less firms entered the market
- More firms exited the market
- Entrants performed better
- **Dropouts** performed **worse**

Table 4: Effect on Firm Turnover and Selection Dynamics

Dep. Var.	Enter1	Enter2	Exit	Exit	ln(Revenue)	ln(Revenue)
Sample	All	All	All	Incumbents	Entrants	Dropouts
	(1)	(2)	(3)	(4)	(5)	(6)
Coal Share \times TCZ	-0.0993*** (0.0307)	-0.0812*** (0.0275)	0.0940*** (0.0246)	0.0713** (0.029)	1.643*** (0.254)	-0.647*** (0.225)
Firm controls	Yes	Yes	Yes	Yes	Yes	Yes
City-by-Industry controls	Yes	Yes	Yes	Yes	Yes	Yes
City-by-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry-by-Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Effect on Induced Innovation



Alternative Hypotheses

- Initial Differences in Performance
 - No difference in 1998
- Price Effect
 - No difference between TFPR and TFPQ
- Unobserved Government Policies
 - No difference between state-owned and private firms
- Alternative measure of pollution intensity
 - Similar findings using SO₂ emissions

Decomposition Exercise

$$P = V\theta'z$$

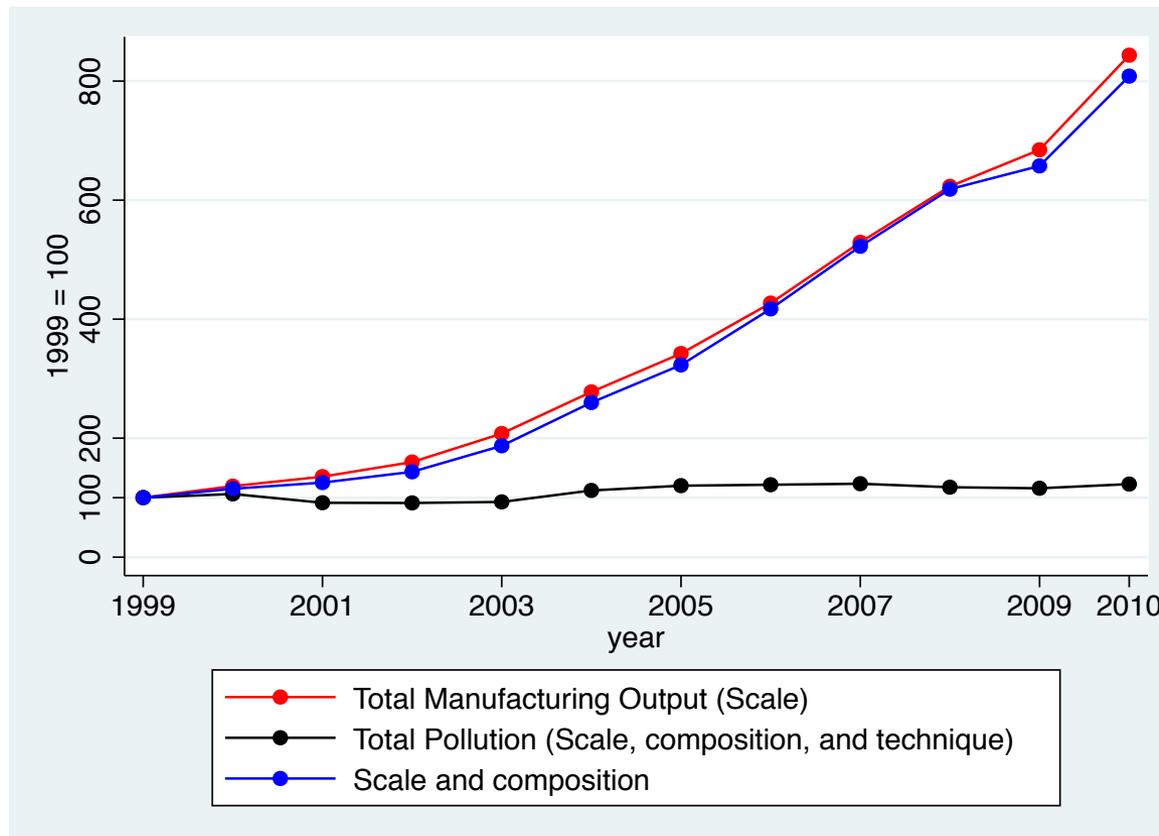
$$dP = \underbrace{\theta'z}_{\text{Total pollution change}} dV + \underbrace{vz'}_{\text{Scale effect}} d\theta + \underbrace{V\theta'}_{\text{Composition effect}} dz$$

Total pollution change Scale effect Composition effect Technique effect

- P = total pollution
- V = total value of shipment
- θ = market share of each industry
- z = pollution intensity

Decomposition Exercise

- **800%** Increase in Manufacturing Output
- Only **23%** increase in SO₂ emissions

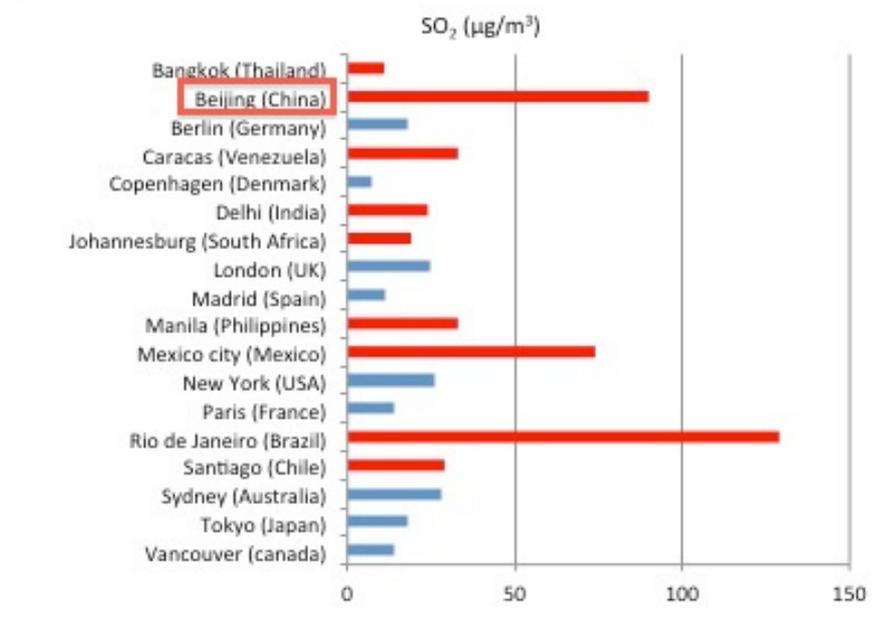
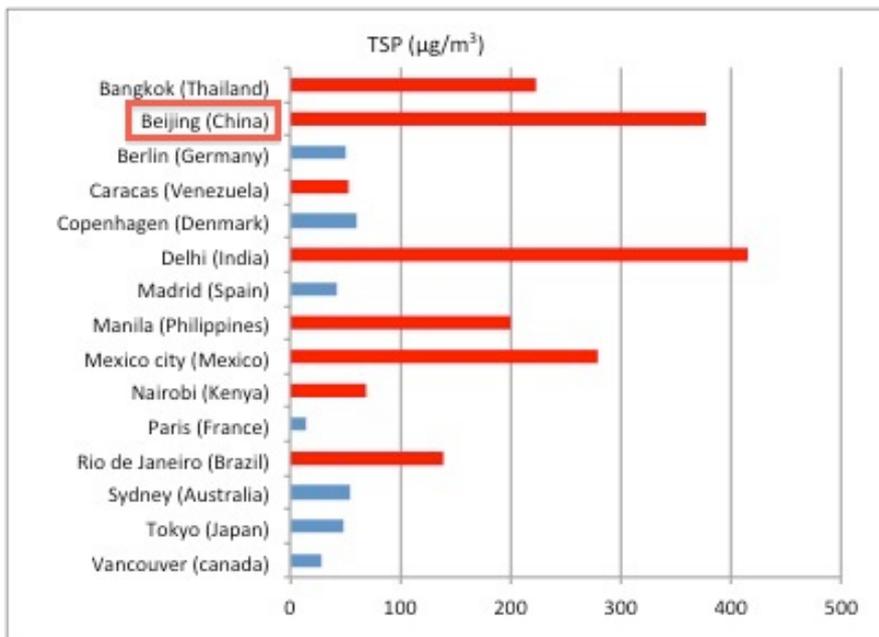


Conclusions

- Policy Implications
 - Net benefits on competitiveness in polluting industries
 - Mechanism 1: greater market dynamics
 - Mechanism 2: induced innovation
- World Implications
 - Overstating the costs by focusing on firm level
 - Global warming

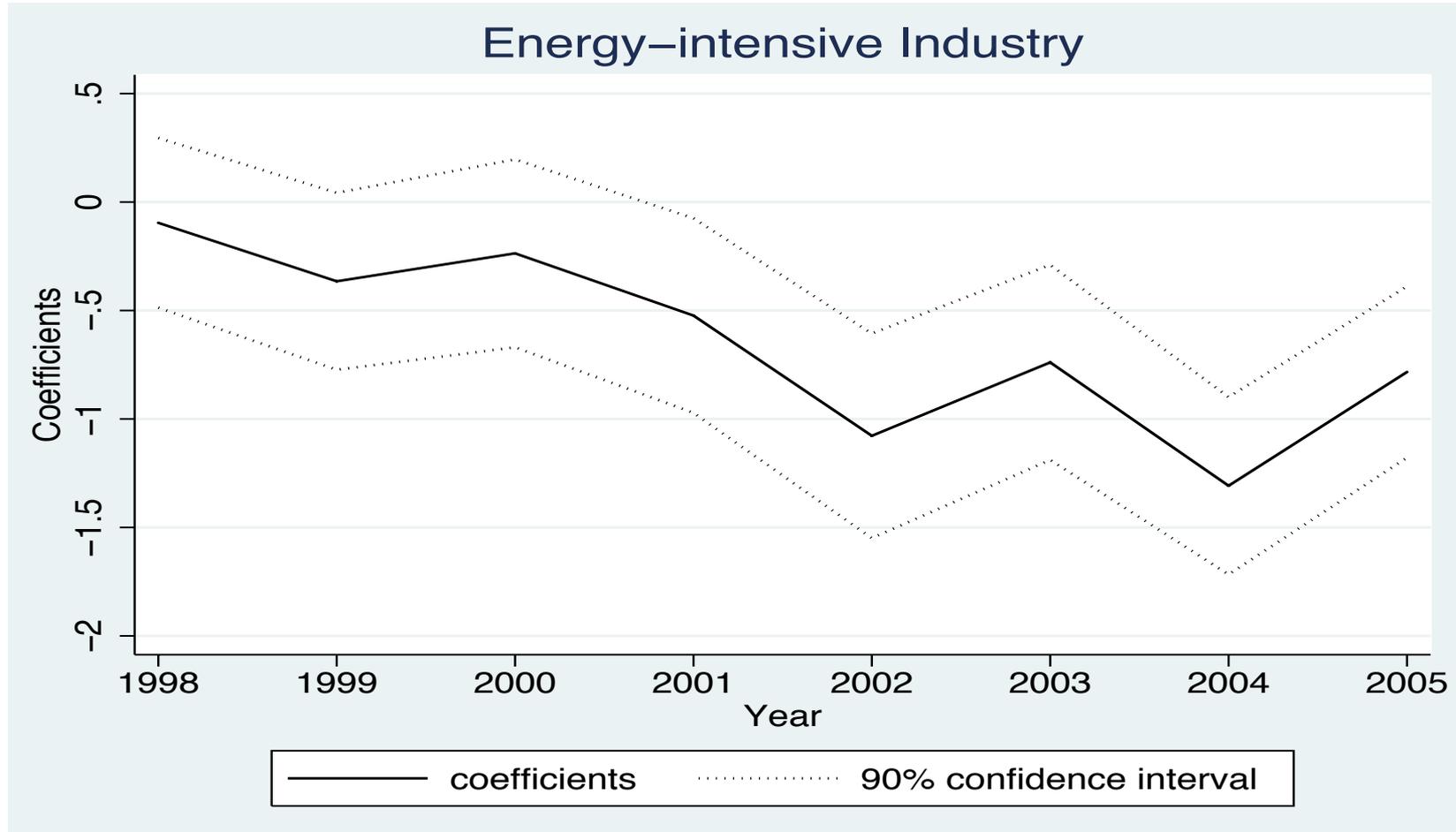
Appendix

Motivations



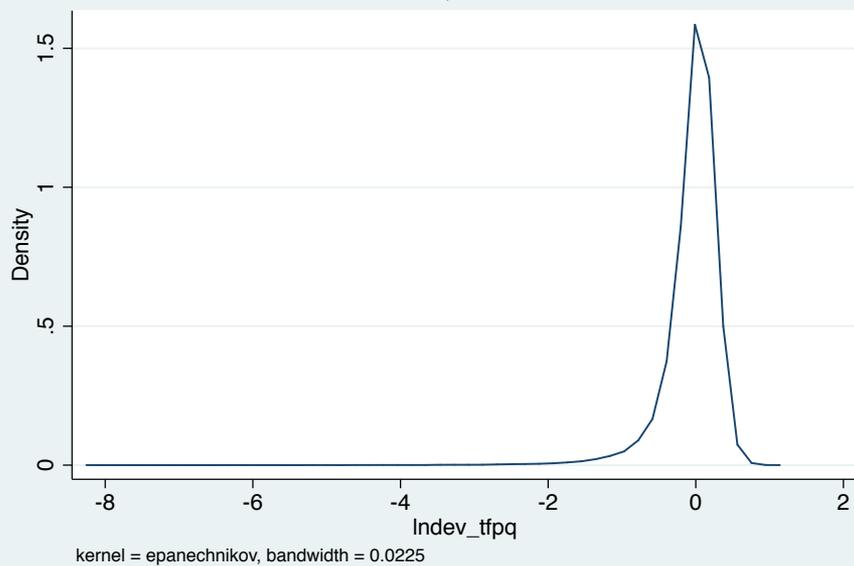
Source: WDI (1995)

Dynamic Effect

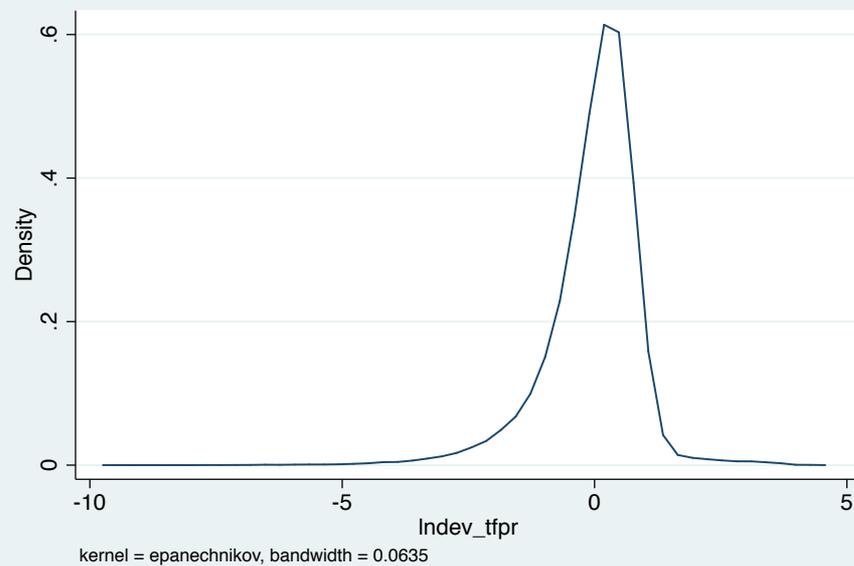


“Misallocation” of Resources

TFPQ in 1998



TFPR in 1998



Pollution and Energy Intensity, by Industry

Code	Industry	SO ₂	Coal	Energy
13	Agricultural byproduct processing	0.00%	1.27%	1.50%
14	Food industry / manufacturing of food	3.05%	0.88%	0.92%
15	Beverage industry/ manufacture of beverage	3.05%	0.71%	0.76%
16	Tobacco industry / manufacture of tobacco	3.05%	0.14%	0.17%
17	Textile industry	2.02%	1.84%	2.69%
18	Textile garments, footwear and headgear industry/ manufacturing of textile garments, footwear, footwear and headgear	0.00%	0.09%	0.25%
19	Leather, fur, down and its related manufacturing	0.12%	0.17%	0.22%
20	Processing of timbers and manufacture of wood, bamboo, cane, palm, and straw	0.00%	0.26%	0.29%
21	Manufacture of furniture	0.00%	0.05%	0.08%
22	Manufacture of paper and paper products	2.13%	1.55%	1.63%
23	Printing, reproduction of recording media	0.05%	0.06%	0.16%
24	Manufacture of goods for culture and education, and sports wear	0.00%	0.02%	0.05%
25	Processing of petroleum, coking, processing of nucleus fuel	1.06%	5.83%	4.24%
26	Manufacture of chemical raw material and chemical materials	7.94%	7.85%	12.06%
27	Medical and pharmaceutical manufacturing	0.81%	0.66%	0.92%
28	Chemical fiber manufacturing	1.07%	0.60%	0.97%
29	Manufacture of rubber	0.49%	0.41%	0.49%
30	Manufacture of plastic	0.16%	0.23%	0.41%
31	manufacture of nonmetal minerals	7.30%	9.75%	9.95%
32	Smelting and pressing of ferrous metals	6.25%	9.38%	14.13%
33	Smelting and pressing of nonferrous metals	4.69%	0.98%	2.17%
34	Metal manufacturing	0.16%	0.34%	0.76%
35	General purpose equipment manufacturing	0.00%	0.60%	1.26%
36	Special purpose equipment manufacturing	0.00%	0.47%	0.83%
37	Transport equipment manufacturing	0.00%	0.62%	1.05%
39	Electrical machinery and equipment manufacturing	2.28%	0.25%	0.48%
40	Communication equipment, computer and other electronic equipment	0.00%	0.10%	0.25%
41	Measuring instrument and machinery for culture and educational activity and office work	0.00%	0.05%	0.11%
42	Art work and other manufacturing	0.00%	0.66%	0.94%
43	Recycling and disposal of waste	0.00%	0.00%	0.00%
44	Production and supply of electric power and heating power	55.85%	31.81%	5.38%
45	Production and supply of gas	0.00%	0.55%	0.26%
46	Production and supply of water	0.00%	0.03%	0.37%
	Manufacturing and power sectors total	95.41%	78.23%	65.75%
	National total	13,098,346	137,676.5	131,175.6

Econometric Modeling of Productivity

- Alternative measures of productivity
 - Profits
 - Returns on assets (ROA) = profits/assets
 - Returns on equity (ROE) = profits/equity ownership rights
 - Returns on capital employed (ROCE) = profits/capital employed
 - Net income
 - TFPQ = Physical productivity = $Y/K^\alpha(wL)^{1-\alpha}$
 - TFPR = revenue productivity = $PY/K^\alpha(wL)^{1-\alpha}$

Research Design

- Regulations within TCZ
 - No new coal mines producing coal with a sulfur content higher than 3% can be established, and existing mines that produce such coal must gradually be shut down or reduce output.
 - Construction of any new coal-burning thermal power plants in large and medium-sized prefectures is prohibited.
 - All new and renovated power plants are required to use coal with less than 1 % sulfur content.
 - Existing power plants using coal with sulfur content above 1% are required to install flue gas desulfurization (FGD) equipment.

Research Design

Effectiveness of TCZ Policy

- Substantial fall in SO₂ emissions
 - 23.67 Mt in 1995 → 19.95 Mt in 2000
 - About 71% of all factories in TCZ met the SO₂ emission standard
- Actively shutting down collieries and power plants
 - Collieries, producing high sulfur coal, had been closed
 - 10 Mt reduction in raw coal consumption
 - 0.4 Mt reduction in SO₂ emissions
- Increased compliance to pollution standard
 - Cities in the SO₂ pollution (acid rain) control zone
 - Cities meeting the Class II standard rose by 12.3% (3.3%)
 - Cities meeting the Class III standard increased by 4.2% (7.9%)
 - Cities not meeting the Class III standard fell by 16.5% (11.2%)
- More reductions in TSPs in TCZs
 - 22% reductions in TSPs

Table 1: Descriptive Statistics of Key Variables

Variables	Obs.	Mean	Std. Dev.
Revenues	1,133,821	56,057.18	457,823.49
Profits	1,133,839	2,429.30	41,888.42
ROA	1,136,103	0.11	0.34
ROE	1,136,103	0.22	0.77
ROCE	1,136,103	0.31	0.79
Net income	1,136,103	2,361.82	42,544.76
Capital	1,133,324	16,212.70	112,342.87
Labor	1,136,101	253.14	761.45
Asset	1,120,791	64,229.70	572,319.89
Age	1,103,556	9.41	10.51
Capital intensiveness	1,120,847	87.22	993.62
State ownership	1,136,103	0.22	0.41
Leverage	1,119,529	0.62	0.54
Firms in TCZ	1,136,103	0.69	0.46
Share of coal consumption	1,136,103	0.02	0.04
Share of SO ₂ consumption	1,136,103	0.02	0.05
Share of energy consumption	1,136,103	0.03	0.04

Notes: The level of observation is at firm-by-year over the period of 1998-2005 for 138,617 firms in 1998, growing up to 250,844 firms in 2005. All monetary values are in constant thousand of 2000 RMB. ROA is returns on assets, calculated by the ratio of profits to the beginning-of-year assets, ROE is returns of equity, calculated by profits divided by equity ownership rights, ROCE is returns on capital employed, calculated by the ratio between profits and capital employed. See Online Appendix # for more details on these variable constructions.

Alternative Hypotheses

Table 5: Testing Alternative Hypotheses

Var.	Ln(Revenue) 1998 (1)	TFPQ All (2)	TFPR All (3)	Ln(Revenue) State-owned (4)	Ln(Revenue) Private (5)	Ln(Revenue) All (6)
Share × TCZ	-0.620*** (0.212)	2.779*** (0.267)	0.555*** (0.201)	0.457*** (0.171)	1.261*** (0.205)	0.765*** (0.119)
Log Share × TCZ	-0.144 (0.242)	-3.559*** (0.281)	-1.240*** (0.214)	-1.416*** (0.261)	-0.811*** (0.187)	-0.870*** (0.164)
Observations	97,785	870,873	870,873	203,581	859,983	831,734

: This table presents estimated results based on the robustness checks. Columns (1) and (2) compare differences in the regressions using TFPQ and TFPR, whose definitions are described in Online Appendix. Column (3) presents estimates using the sample in 1998. Columns (4) and (5) compares samples in all years between state-owned firms and private firms. All regressions include city-year fixed effects and industry-year fixed effects. In column (6), we use SO2 share instead of Coal

The robust standard errors clustered as the city-industry level are reported in the parentheses.

<0.01, ** p<0.05, * p<0.1