Regulating Conglomerates in China: Evidence from an Energy Conservation Program

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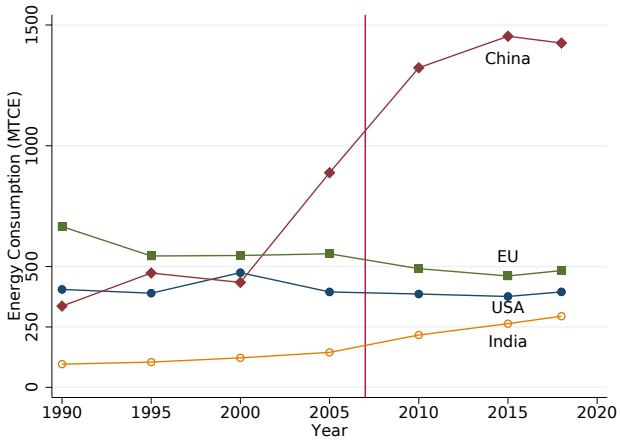
Cross-Country Comparison of Industrial Energy Use



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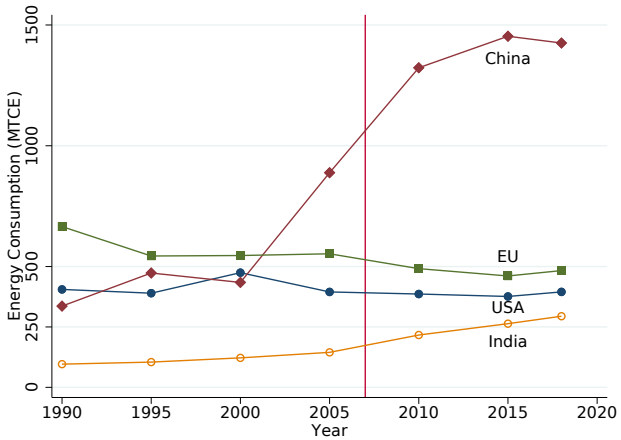

- **Top 1,000 program**
  restricted energy use of very large firms
- Regulated firms consumed:
  - 47% of industrial energy
- Goals:
  1. Reduce energy use by 100 million TCE
  2. Improve energy efficiency

Research Questions

1. How do conglomerates respond to regulation?

- Do regulated firms respond by ↑ efficiency or ↓ output?
- Do conglomerates shift production to unregulated firms in ownership network?

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2. What is the efficiency cost to regulated firms?

- Does the ability to shift production within conglomerate lower the cost?

3. What are the aggregate and welfare effects of the policy?

- How big is equilibrium leakage—within conglomerate & across market?
- What is implied trade-off of output vs benefits of reducing energy use?
- Can information on conglomerate networks improve energy regulation?

Outline

Policy Background

The Top 1,000 Energy Saving Program in China

11th Five Year Plan (2006-2010): Reduce $\frac{\text{energy consumption}}{\text{GDP}}$ by 20%

Top 1,000 Energy Saving Program

- 9 energy-intensive industries
- Energy consumption $>$ 180,000 TCE in 2004
- 33% of China's total energy consumption
- 47% industrial energy use

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Policy Implementation

- Each firm received energy use target
- Local gov't responsible for implementation
- "One vote veto" $\longrightarrow$ 98% firms reach target by 2010

more policy details

The Top 10,000 Energy Saving Program in China

12th Five Year Plan (2012-2015): Expanded Top 1,000 program

Top 10,000 Energy Saving Program

- Energy consumption $>$ 10,000 TCE in 2010
- 60 % of China's total energy consumption
- Goal: save 250 MTCE & improve firms' energy efficiency

Use Top 10,000 as controls if not regulated by Top 1,000 program

How Do Regulated Firms Respond to the Policy?

Difference-in-Differences Approach

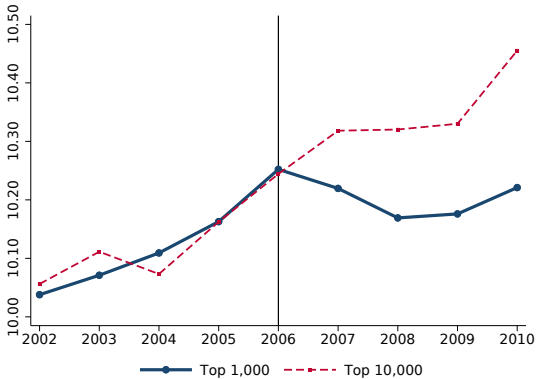
Regression specification:

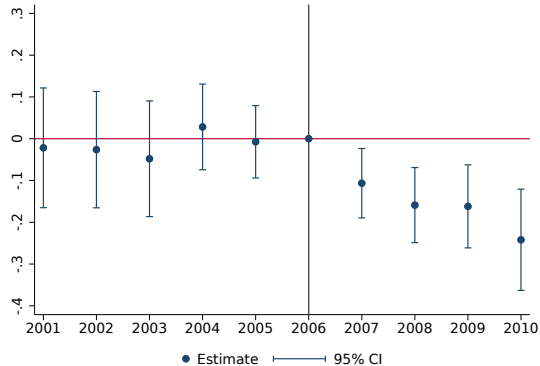
$$Y_{ijkt} = \beta treat_i \times post_t + \alpha_i + \eta_{jt} + \delta_{kt} + \varepsilon_{ijkt}$$

- Y independent variables
  - i firm
  - j industry
  - k province
  - t year
- Log-Energy, Log-Output (Sales), Log-Energy Efficiency

$treat$	Top 1,000 firms
$control$	Top 10,000 firms
$post$	policy implementation year 2007
α_i	firm fixed effects
η_{jt}	industry×year fixed effects
δ_{kt}	province×year fixed effects
ε_{ijkt}	clustered at firm level

Parallel Trends: Energy Use





Data: Environmental Statistics Database

Difference-in-Differences Results

Variables	Energy	Sales	Energy Efficiency
Treat × Post	-0.156***	-0.204***	-0.049
	(0.047)	(0.042)	(0.046)
Observations	23,151	22,991	22,991
R^2	0.892	0.889	0.842
Firm FE	Y	Y	Y
Industry × Year FE	Y	Y	Y
Province × Year FE	Y	Y	Y

- Regulated firms ↓ energy use by 12-16% ≈ 100 million tons of coal equivalent
- Sales ↓ $10 - 23\%$
- Null effect on energy efficiency: 95% CI $[-14\%, 4.3\%]$

▸ industry hetero.

▸ more ▸ other policy

How do Conglomerates Respond to the Policy?

Related Types: Affiliates & Investment

Figure: Affiliates

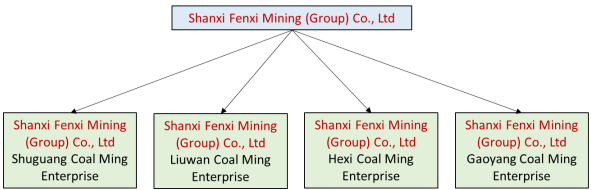
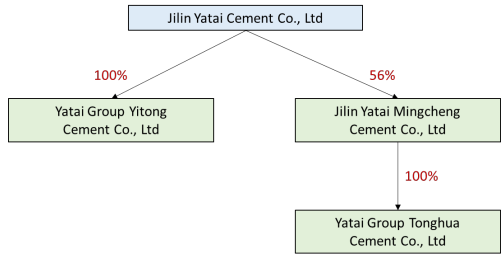


Figure: Investment



- Restrict to 25% ownership and 2 investment levels

Related Types: Shareholders & Shareholders' Investment

Figure: Shareholder

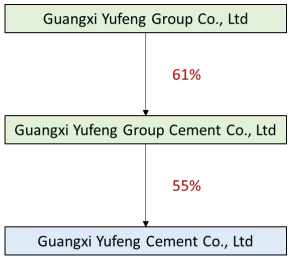
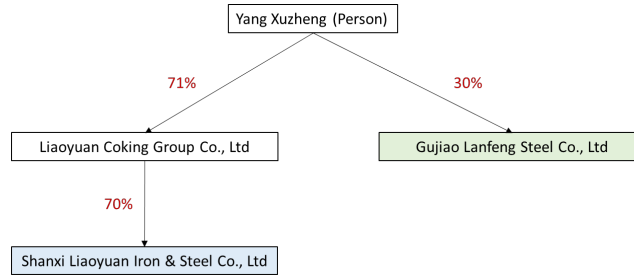


Figure: Shareholder's Investment



Robustness

Conglomerate Spillover: DID Approach

Regression specification:

$$Y_{ijkt} = \beta Related_i \times post_t + X_{it}\gamma + \alpha_i + \eta_{jt} + \delta_{kt} + \epsilon_{ijkt}$$

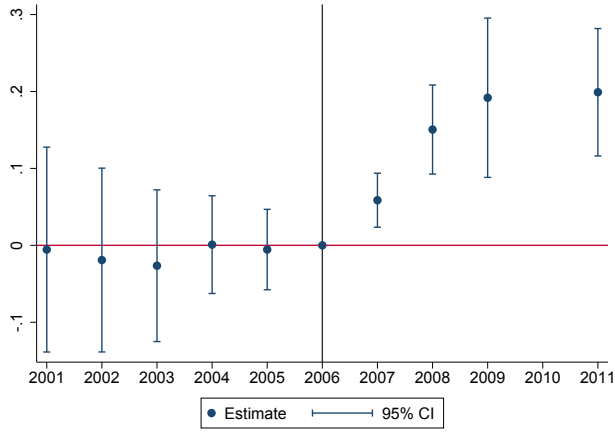
Control group:

- Match related firms to other unregulated firms
- Match on firm size prior to the policy
- Restrict sample to: (1) industrial firms above designated size
  (2) same 4-digit industries

Placebo Test: Firms in Other Industries

- Related firms in 2-digit industries (not in 4-digit industry of regulated firm)

Graphical Evidence: Conglomerate Spillover



Data: Survey of Industrial Firms

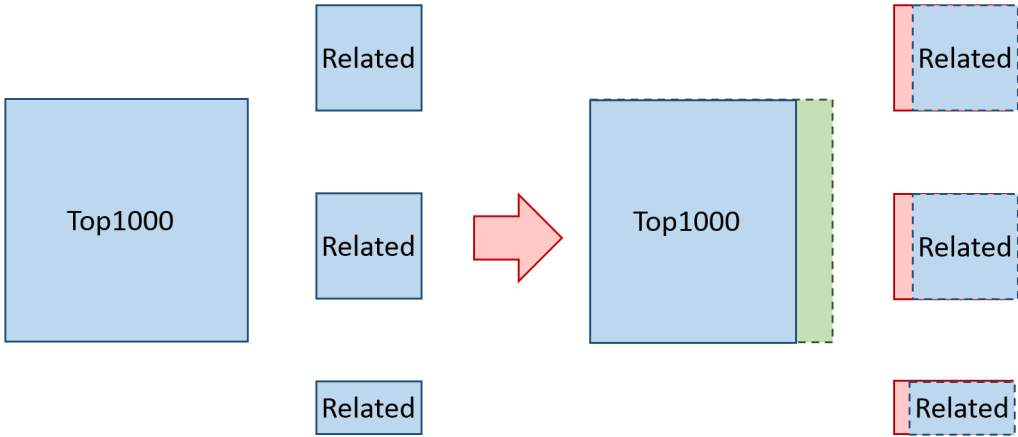
Difference-in-Differences Results

Variables	Sales	Energy Efficiency	Placebo Output
Treat × Post	0.118***	-0.059	-0.015
	(0.042)	(0.080)	(0.039)
Observations	18,418	3,668	8,905
R^2	0.881	0.880	0.911
Firm FE	Y	Y	Y
Industry × Year FE	Y	Y	Y
Province × Year FE	Y	Y	Y

- Sales in related firms (in same 4-digit industry) ↑ 12%
- No impact on energy efficiency
- Null effect on placebo related (outside 4-digit industry)

▸ geography ▸ more ▸ industry hetero.

Conglomerate Spillover: Interpretation



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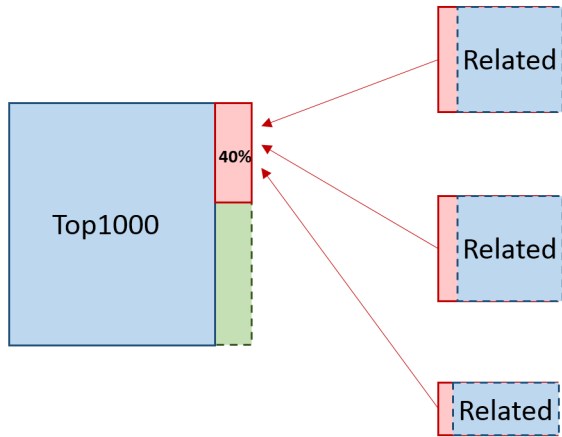


- Conglomerates avoid a significant part of the regulation, but not all of it

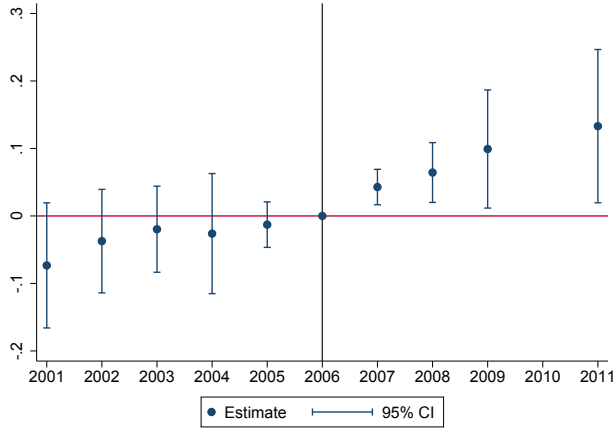
Market Spillover

Regression specification:

$$ln(Output)_{ijt} = \beta spillover_j \times post_t + X_{it}\gamma + \alpha_i + \tau_t + \epsilon_{ijt}$$

- $spillover_j$ policy intensity in industry j
  - $spillover_j = \frac{\text{Top 1,000 energy-saving target}}{\text{total energy consumption in 2004}}$
  - Normalized by average industry exposure
- Sample: industrial firms excluding Top 1,000 and related firms

Graphical Evidence of Market-Level Spillovers



Data: Survey of Industrial Firms

- On average, regulation ↑ output of unregulated firms by 7-8%

Market Spillover: Results

Variables	ln(Sales)			
	All Sample		Energy-Intensive Industries	
Spillover × Post	0.081***	0.073***	0.083***	0.084**
	(0.022)	(0.019)	(0.023)	(0.027)
Observations	2,557,940	2,557,940	843,313	843,313
R^2	0.840	0.856	0.831	0.848
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry-level Controls	Y	Y	Y	Y
Firm-level Controls		Y		Y

Synthesizing Empirical Results

Insights from empirical results:

- Regulated firms cut output instead of improving efficiency
- Conglomerates shift production to related parties
- Unregulated firms benefit from regulation

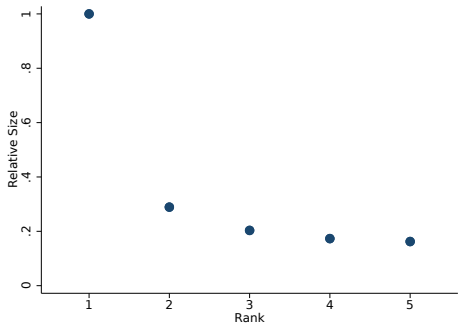
Limits to reduced-form analysis:

- Interpret DID in the presence of conglomerate and market spillovers
- Measure shadow cost of regulation and aggregate trade-offs
- Simulate effects of different regulations

What are the Efficiency Costs of the Policy?

Model Setup: Technology

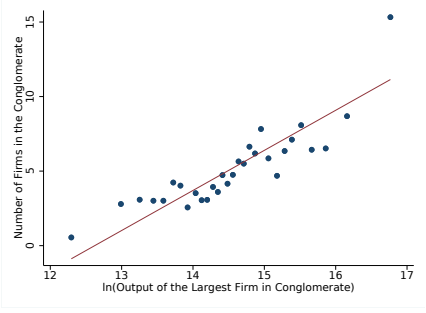
- Firm inputs: $k_i, \min\{l_i, \nu e_i\}$, DRTS $\alpha_l + \alpha_k = \alpha < 1$
- Cobb-Douglas production: $q(\phi, i) = \phi \delta^{i-1} k_i^{\alpha_k} l_i^{\alpha_l}$, $\phi \sim \mathcal{LN}(0, \sigma_m)$



- Conglomerate output $q(\phi, n) = \left[\sum_{i=1}^{n} q(\phi, i)^{\rho_c}\right]^{1/\rho_c}$ (Baseline: $\rho_c = 1$)

Model Setup: Demand and Conglomerate Size

- CES demand for conglomerate output: $p = R^{1-\rho} P^{\rho} q^{\rho-1}$
- Conglomerate choose n subject to fixed cost f: $\pi(\phi) = max_n \pi(\phi, n) - rnf$
- Conglomerate size increases with output of largest firm



- Long-run free-entry condition: $\mathbb{E}[\pi(\phi)] \geq f_e$

Profit Maximization and Optimal Conglomerate Size

1. Given (ϕ, n) firms maximize

$$\pi(\phi, n) = \max_{\{l_i\}_{i=1}^n, \{k_i\}_{i=1}^n} \left\{ R^{1-\rho} P^{\rho} \left[\sum_{i=1}^{n} \phi \delta^{i-1} k_i^{\alpha_k} l_i^{\alpha_l} \right]^{\rho} - (w + p_e) \sum_{i=1}^{n} l_i - r \sum_{i=1}^{n} k_i \right\}$$

$\Longrightarrow$ Within-conglomerate allocation: $\frac{q_i}{q_1} = \frac{k_i}{k_1} = \frac{l_i}{l_1} = \delta^{\frac{i-1}{1-\alpha}}$

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2. Given n and conglomerate productivity $\phi\Delta_n = \phi[\sum_{i=1}^{n} (\delta^{i-1})^{\frac{1}{1-\alpha}}]^{1-\alpha}$

$$\pi(\phi, n) = R^{\frac{1-\rho}{1-\alpha\rho}} P^{\frac{\rho}{1-\alpha\rho}} C_{\pi} \left(\phi\Delta_n\right)^{\frac{\rho}{1-\alpha\rho}}$$

$\Longrightarrow$ Add affiliate if $\pi(\phi, n+1) - \pi(\phi, n) \geq rf$
Cut-off rule: conglomerates have n affiliates when $\phi_n \leq \phi < \phi_{n+1}$

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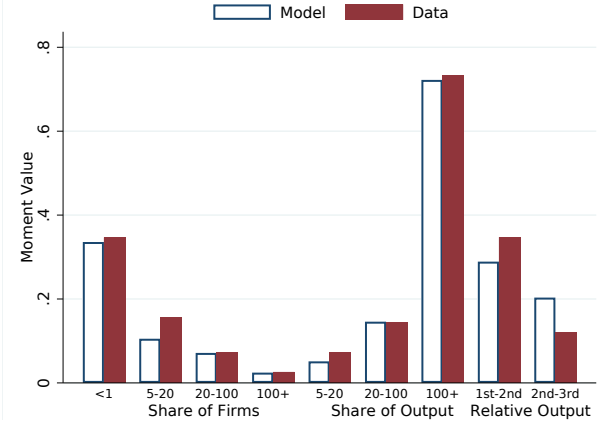
3. Equilibrium: entry condition and product market clearing

more

Method of Moment Estimation using Pre-Regulation Data

- Calibrate $\alpha = 0.9$ (Burnside et al. 1995) and $\sigma = \frac{1}{1-\rho} = 4$ (Melitz & Redding, 2015)
- Estimate parameters (δ, σ_m, f) targeting output & firm size distribution and within-conglomerate distribution **before regulation**



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Regulation Distorts Conglomerate Production

- For conglomerates $\phi > \tilde{\phi}$, regulation caps energy of largest firm at $\xi < 1$ of prior use
- With fixed size n and capital $\{k_i^*\}$, conglomerate:

$$\max_{l_1, l_2 \ldots l_n} \left\{ R^{1-\rho} P^{\rho} q(\phi, n)^{\rho} - (w + p_e) \sum_{i}^{n} l_i \right\} \text{ subject to } l_1 < \xi l_1^*$$

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- Conglomerate FOC for l_i:

$$\underbrace{R^{1-\rho} P^{\rho}}_{\text{Market Demand}} \times \underbrace{\rho [q(\phi, n)]^{\rho - 1}}_{\text{Residual Revenue Effect}} \times \underbrace{\alpha_l \delta^{i-1} \phi (k_i^*)^{\alpha_k} (l_i)^{\alpha_l - 1}}_{\text{Marginal Product of } l_i} = w + p_e + \underbrace{\lambda(\phi) \mathbb{I}[i = 1]}_{\text{Shadow Cost}}$$

- Regulation distorts within-conglomerate allocation of production:

$$\frac{q_i}{q_1} = \delta^{\frac{i-1}{1-\alpha}} \left[1 + \frac{\lambda(\phi)}{w + p_e} \right]^{\frac{\alpha_l}{1-\alpha_l}}$$

From Shadow Cost to Aggregates

- Summarizing conglomerate distortions (and conglomerate spillovers) from regulation

$$\frac{q(\phi,n)}{q^*(\phi,n)} = \underbrace{\frac{\xi^{\alpha_l}\left[1+(\Delta_n^{\frac{1}{1-\alpha}}-1)\left[1+\frac{\lambda(\phi)}{w+p_e}\right]^{\frac{\alpha_l}{1-\alpha_l}}\right]}{\Delta_n^{\frac{1}{1-\alpha}}}}_{=\xi_q(\phi)}$$

- Characterizing aggregate price (and market spillovers) after regulation

$$\left(\frac{P}{P^*}\right)^{-\rho} = (1-s_{\tilde{\phi}})\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho^2}{1-\alpha_l\rho}} + s_{\tilde{\phi}}\mathbb{E}_e\left[\xi_q(\phi)^\rho \,\middle|\, \phi > \tilde{\phi}\right]$$

- Can similarly characterize conglomerate and market leakage of energy, $\frac{E}{E^*}$ more

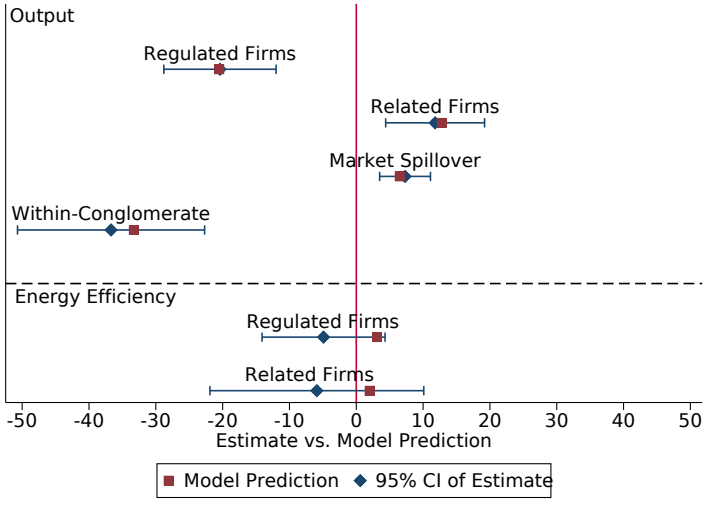
Top 1,000 Program: Model Predictions

Model implications of Top 1,000 program:

- Regulated firms shrink due to input quota
- Unregulated firms in conglomerate expand:
  1. Within-conglomerate substitution
  2. Market spillover
- Other firms expand through market spillover

Model Matches Estimated Effects of Regulation

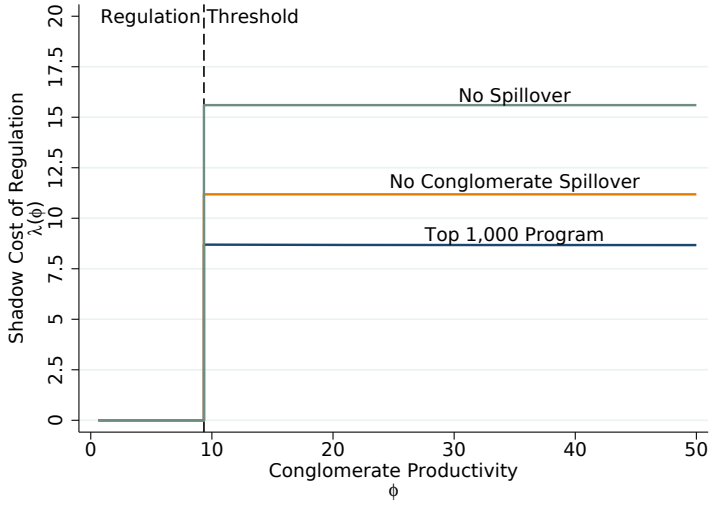
Policy threshold	$\tilde{\phi}$	6.31	Energy share of Top1000 firms
Input quota	$1-\xi$	0.20	11th Five Year Plan



Out-of-Sample: Model-based DID of Regulation

Ln (Revenue)	Within-Congl. Effect	Across-Congl. Effect	Market Effect	Total Effect
A. Effect on Regulated Firms				
Top 1,000 Firms	-0.129	-0.037	0.026	-0.140
Control Firms	0	0.039	0.026	0.065
Difference-in-Differences	-0.129	-0.076	0	-0.205
B. Effect on Related Firms				
Related Firms	0.204	-0.037	0.026	0.193
Control Firms	0	0.039	0.026	0.065
Difference-in-Differences	0.204	-0.076	0	0.128
C. Within-Conglomerate Effect				
Difference-in-Differences	-0.333	0	0	-0.333

Shadow Cost: Counterfactual



What are the Welfare Effects of the Policy?

Welfare Effects of Energy Policies

- Welfare effects of policies depend on:
  - Shadow costs λ_n
  - Equilibrium price response
  - Leakage to non-regulated firms
- Model characterizes aggregate effects analytically
- Evaluate welfare assuming

$$W = \left(\frac{R}{P}\right)^{1-\kappa} \times \underbrace{\left(\frac{1}{\beta_0 E}\right)^{\kappa_0}}_{\text{C02 Emissions}} \times \underbrace{\left(\frac{1}{\beta_1 E}\right)^{\kappa_1}}_{\text{Local Pollution}}$$

- Where $\kappa = \kappa_0 + \kappa_1$

Welfare Effects of Energy Policies

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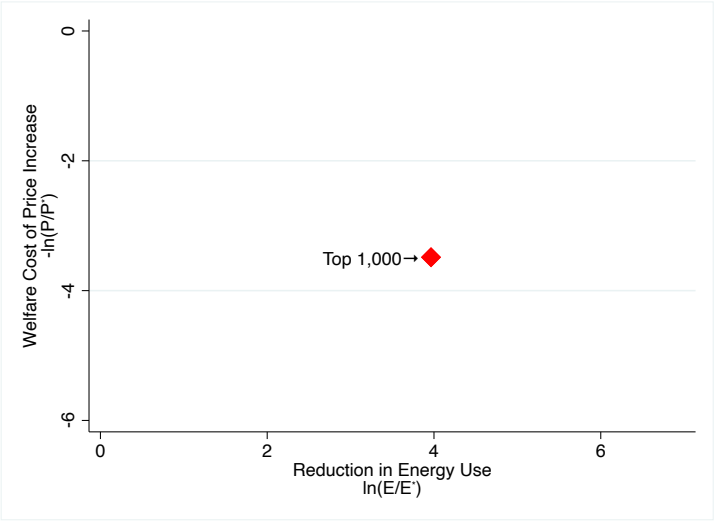
$$W = \left(\frac{R}{P}\right)^{1-\kappa} \left(\frac{1}{\beta_0 E}\right)^{\kappa_0} \left(\frac{1}{\beta_1 E}\right)^{\kappa_1} \Longrightarrow \frac{d \ln W}{1-\kappa} = -\ln\left(\frac{P}{P^*}\right) - \frac{\kappa}{1-\kappa} \ln\left(\frac{E}{E^*}\right)$$

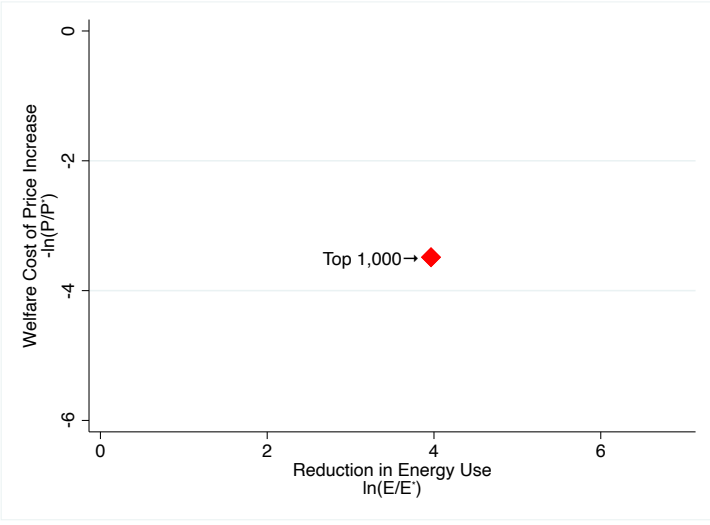
- Calibrate $\kappa = \kappa_0 + \kappa_1$ to 2006 data:

$$\kappa = \frac{\text{Government Willingness To Pay} \times \text{Carbon Emissions}_{2006}}{\text{Aggregate Income}_{2006} \times 0.8}$$

Welfare Effects of Energy Policies

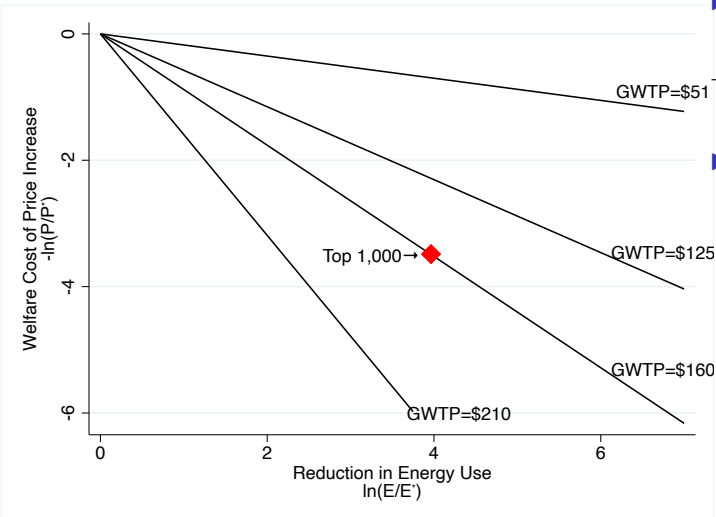


Welfare Effects of Energy Policies



- Top 1,000 firms ↓ energy by 100 MTCE
- After conglomerate spillover, energy ↓ by 60 MTCE
- Aggregate energy ↓ by 3.96% → 48 MTCE

Welfare Effects of Energy Policies



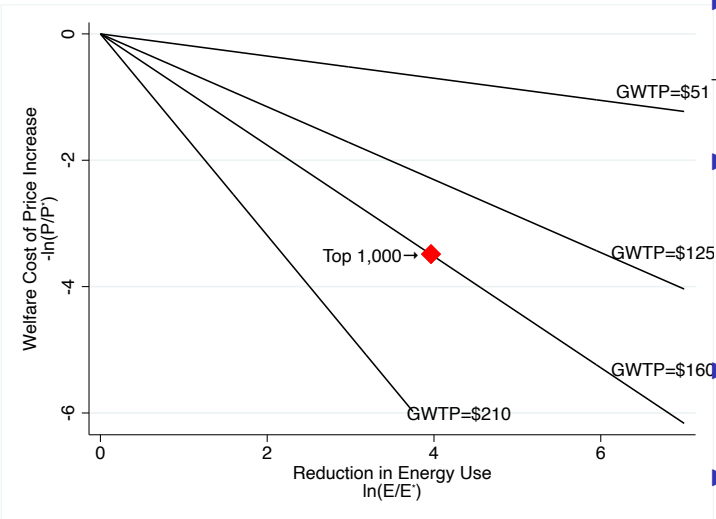
- Welfare:

$$-\ln\left(\frac{P}{P^*}\right)-\frac{\kappa}{1-\kappa}\ln\left(\frac{E}{E^*}\right)$$

- Calibrate κ:

$$\kappa = \frac{\text{GWTP} \times \text{C02}_{2006}}{\text{GDP}_{2006} \times 0.8}$$

Welfare Effects of Energy Policies



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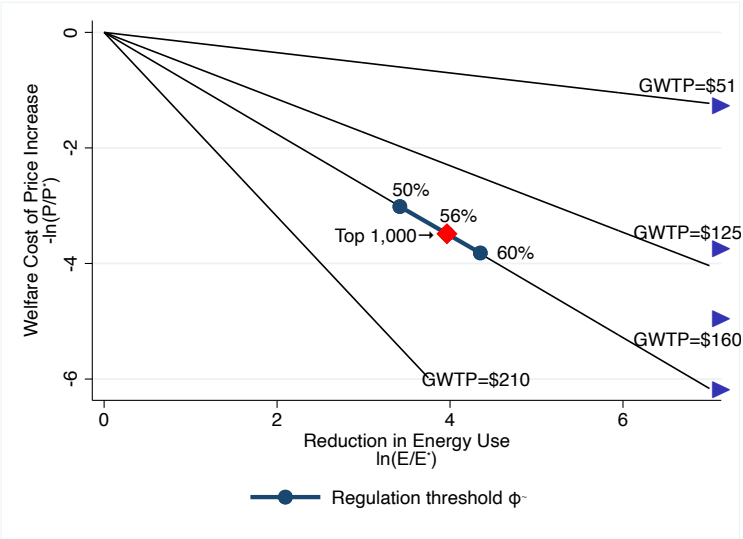
- Pollution damages ton of carbon: \$4-\$17
- SCC $\in$ [\$143 – \$156]

▸ Robustness

Welfare Effects of Energy Policies



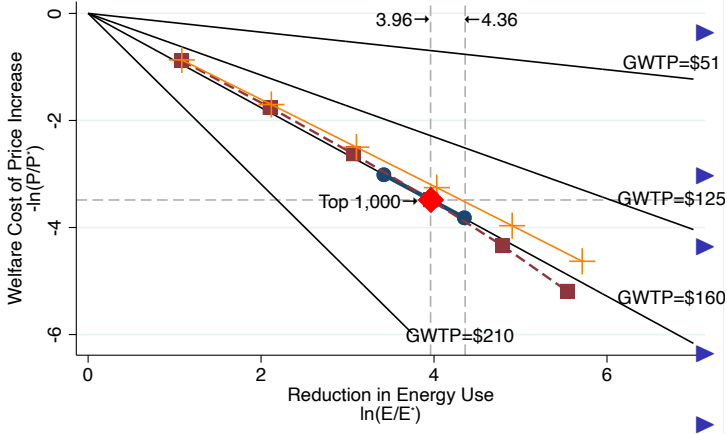
Top 10,000 program increased number of firms in program

Equivalent to lowering $\tilde{\phi}$

Similar trade-off

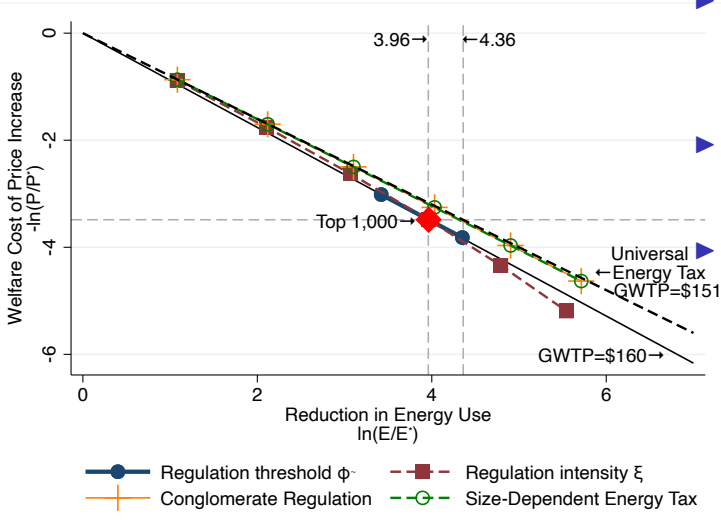
Higher admin cost from regulating 14,000 firms

Welfare Effects of Energy Policies



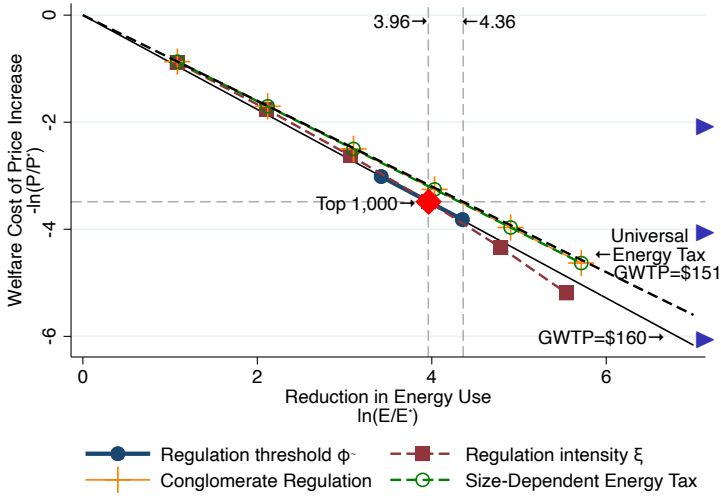
- Alternative regulation: limit energy use at conglomerate level
- GWTP=$152
- For same price increase, lower energy use by 10%
- Saves 5 MTCE
- Small increase in admin cost (3,500 firms)

Welfare Effects of Energy Policies



- Alternative regulation: size-dependent energy tax
- Similar to conglomerate regulation
- Very small loss relative to universal energy tax

Welfare Effects of Energy Policies



- Alternative regulation: size-dependent energy tax
- Similar to conglomerate regulation
- Very small loss relative to universal energy tax
- $GWTP \in [\$112, \$197]$ with endogenous and heterogeneous energy efficiencies, alternative parameter values

More

Takeaways

Effects of Top 1,000 Program

- Regulated firms cut output instead of investing in energy efficiency
- Regulated conglomerates shift 40% of production drop to related parties

Efficiency Costs of Program

- Shifting production lowers shadow cost of regulation
- Regulation can improve by targeting conglomerates

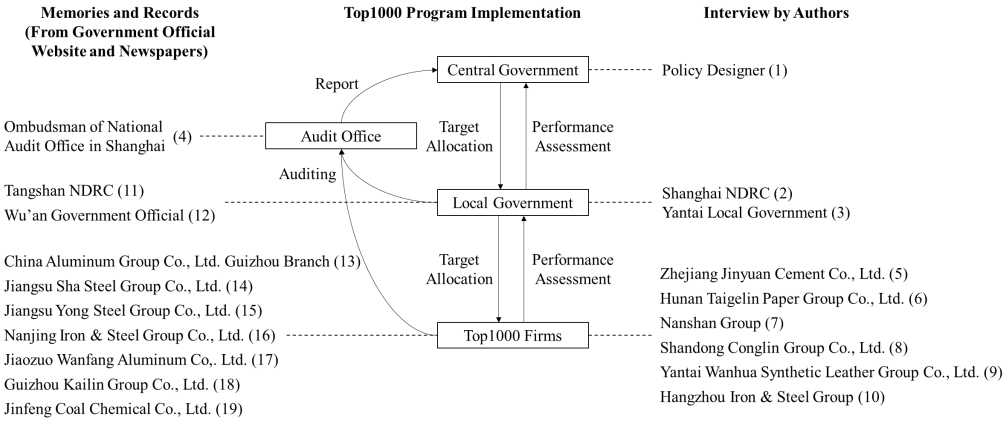
Welfare Effects of Program

- $GWTP = \$160$ rationalizes policy
- Conglomerate regulation and energy tax can increase energy saving by 10%

Additional Slides

Policy Details

Figure: **Interview Record**



Policy Details

- Policy Motivations
  - the rapid development of heavy manufacturing industry
  - the potential for energy shortages to become a key bottleneck for economic development
  - the energy efficiency of the Chinese economy lagged that of developed economies.
  - briefly mentions environmental benefits, although focused on carbon emissions.
- Policy Implementations
  - program was originally designed based on “energy saving”, a conceptual measure the government previously circulated in the 1990s.
  - local government has limited ability to audit and the firms could choose (and game) the favorite formulas
  - in practice, the local government relied on energy use quotas to directly limit regulated firms’ energy consumption.
- Evaluation and Enforcement: cut the power or/and directly put on the coal quota

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Distribution of Top 1,000 Firms by Industry

Industry	Energy Consumption (10,000 tons of SCE)	Proportion (%)	Firm Number
Iron & Steel	22528.63	30.72	249
Electric Power	16249.64	22.16	144
Chemical	10909.29	14.88	238
Petroleum & Petrochemical	10581.76	14.43	98
Mining	5278.77	7.2	60
Non-ferrous	2993.08	4.08	70
Building & Decorative Materials	2913.19	3.97	93
Pulp & Paper Making	961.36	1.31	24
Textile	915.57	1.25	22

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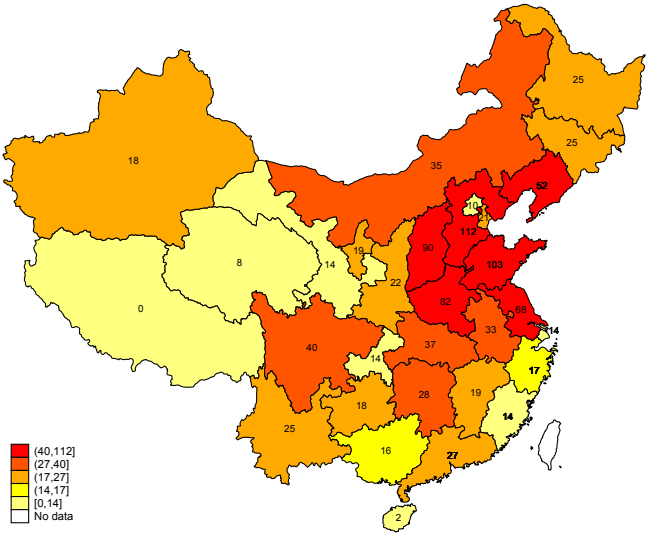
Geographical Distribution of Top 1,000



Top 1,000 Firm Compliance

Table: Firm Compliance

	Orig.list	Evaluation			
Year		2007	2008	2009	2010
Firm Number	1008	953	922	901	881
Non-compliant firms	-	74	36	28	15
Non-compliant rates	-	7.8%	3.9%	3.1%	1.7%

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Difference-in-Differences: Model-Based Interpretation

Model implies that output in firm i of conglomerate l takes the form:

$$\ln \text{Output}_{ijlt} = \underbrace{\ln(\text{Production Share}_{ijlt})}_{\text{Allocation Effect}} + \underbrace{\ln(R_{jt}^{1-\rho} P_{jt}^{\rho})}_{\text{Market Demand}} + \underbrace{\rho \ln\left(\sum_{i \in l} q_{ijlt}\right)}_{\text{Residual Revenue}}$$

Difference-in-Differences: Model-Based Interpretation

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Diff in Reg. Firms:	$\downarrow$	$\uparrow$	$\downarrow$

Difference-in-Differences: Model-Based Interpretation

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Diff in Reg. Firms:	$\downarrow$	$\uparrow$	$\downarrow$
Diff in Control Firms:	0	$\uparrow$	$\uparrow$

Difference-in-Differences: Model-Based Interpretation

Model implies that output in firm i of conglomerate l takes the form:

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Diff in Reg. Firms:	$\downarrow$	$\uparrow$	$\downarrow$
Diff in Control Firms:	0	$\uparrow$	$\uparrow$
		Industry-Year FEs or Matching	

Difference-in-Differences: Model-Based Interpretation

Model implies that output in firm i of conglomerate l takes the form:

$\ln \text{Output}_{ijlt} =$	$\underbrace{\ln(\text{Production Share}_{ijlt})}_{\text{Allocation Effect}}$	$+\ \underbrace{\ln(R_{jt}^{1-\rho} P_{jt}^{\rho})}_{\text{Market Demand}}$	$+\ \underbrace{\rho \ln\left(\sum_{i \in l} q_{ijlt}\right)}_{\text{Residual Revenue}}$
Diff in Reg. Firms:	$\downarrow$	$\uparrow$	$\downarrow$
Diff in Control Firms:	0	$\uparrow$	$\uparrow$
		Industry-Year FEs or Matching	
Diff-in-Diff:	$-$	0	$-$

- DD Estimate=Allocation Effect+Shift in Residual Revenue<Allocation Effect< 0

Difference-in-Differences: Model-Based Interpretation

Model implies that output in firm i of conglomerate l takes the form:

$$\ln \text{Output}_{ijlt} = \underbrace{\ln(\text{Production Share}_{ijlt})}_{\text{Allocation Effect}} + \underbrace{\ln(R_{jt}^{1-\rho} P_{jt}^{\rho})}_{\text{Market Demand}} + \underbrace{\rho \ln\left(\sum_{i \in l} q_{ijlt}\right)}_{\text{Residual Revenue}}$$

Diff in Related Firms:	$\uparrow$	$\uparrow$	$\downarrow$
Diff in Control Firms:	0	$\uparrow$	$\uparrow$
		Industry-Year FEs or Matching	
Diff-in-Diff:	$+$	0	$-$

- DD Estimate=0<Allocation Effect+Shift in Residual Revenue<Allocation Effect

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Difference-in-Differences Results: Energy Use

Variables	ln(Energy Use)			
Treat × Post	-0.125***	-0.156***	-0.156***	-0.129***
	(0.042)	(0.045)	(0.047)	(0.048)
Observations	23,607	23,602	23,151	20,587
R^2	0.887	0.890	0.892	0.898
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry × Year FE		Y	Y	Y
Province × Year FE			Y	Y
Firm-level Controls				Y

- Regulated firms ↓ energy use by 12-16% ≈ 100 million tons of coal equivalent

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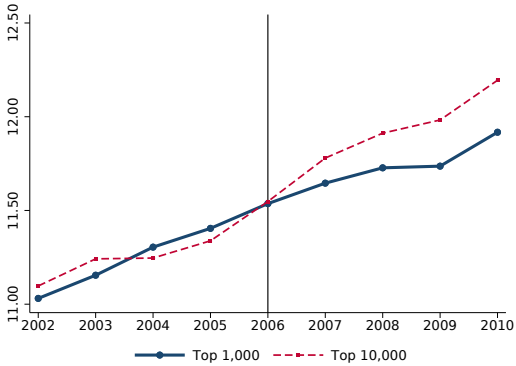
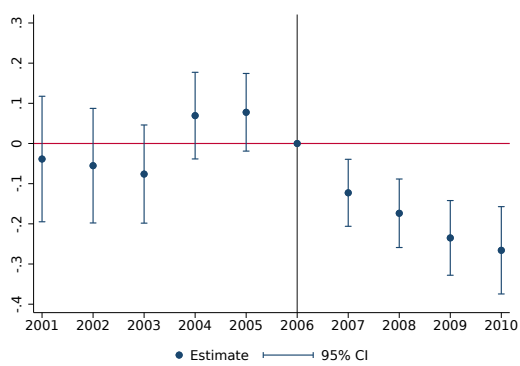
Parallel Trends: Output





Data: Environmental Statistics Database

- Output decreases by $10 - 23\%$

Difference-in-Differences Results: Output

Variables	ln(Output)			
Treat × Post	-0.096**	-0.226***	-0.204***	-0.145***
	(0.040)	(0.041)	(0.042)	(0.042)
Observations	23,435	23,430	22,991	20,462
R^2	0.881	0.887	0.889	0.893
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry × Year FE		Y	Y	Y
Province × Year FE			Y	Y
Firm-level Controls				Y

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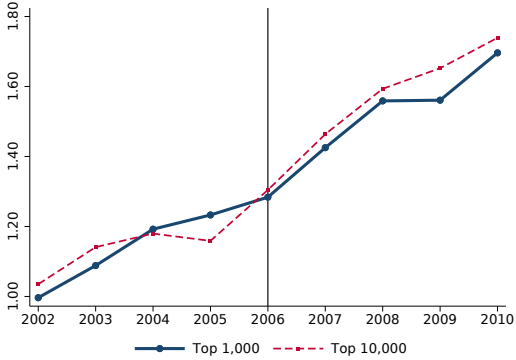
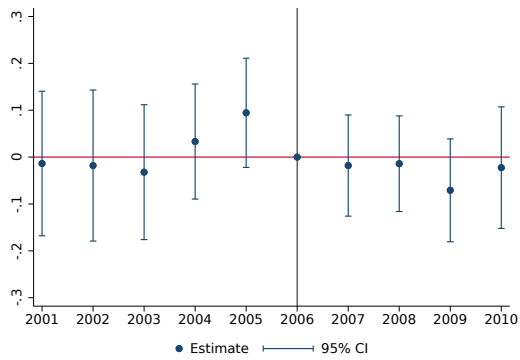
Parallel Trends: Energy Efficiency





Data: Environmental Statistics Database

- Null effect on energy efficiency: 95% CI $[-14\%, 4.3\%]$

Difference-in-Differences Results: Energy Efficiency

Variables	ln(Energy Effiency)			
Treat × Post	0.032	-0.069	-0.049	-0.017
	(0.042)	(0.044)	(0.046)	(0.047)
Observations	23,435	23,430	22,991	20,462
R^2	0.837	0.840	0.842	0.848
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry × Year FE		Y	Y	Y
Province × Year FE			Y	Y
Firm-level Controls				Y

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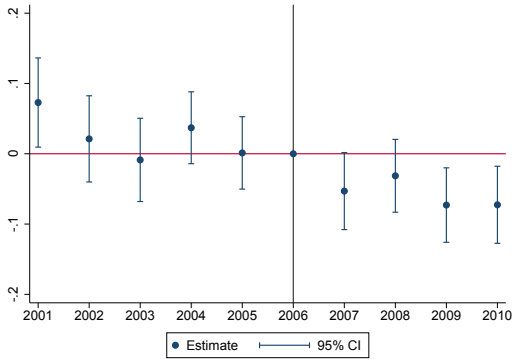
Parallel Trends: Investment



DID Results: Investment(Extensive Margin)

Variables	If Firm Invest			
Treat × Post	-0.057***	-0.071***	-0.072***	-0.071***
	(0.013)	(0.014)	(0.014)	(0.014)
Observations	50,987	50,967	50,967	49,346
R^2	0.191	0.200	0.208	0.212
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry × Year FE		Y	Y	Y
Province × Year FE			Y	Y
Firm-level Controls				Y

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Table: **Robustness to Consideration of Concurrent Policies**

A. Effects of Concurrent Policies on Top 1,000 Firms

	ln(Energy Use)	ln(Output)	ln(Energy Efficiency)
Monitor × Post	-0.003	0.023	0.019
	(0.097)	(0.089)	(0.106)
Observations	3,358	3,322	3,322

B. Robustness to Effects on Top 1,000 Firms

	ln(Energy Use)	ln(Output)	ln(Energy Efficiency)
Treat × Post	-0.186***	-0.234***	-0.046
	(0.075)	(0.080)	(0.083)
Observations	20,655	20,511	20,511

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Table: **Heterogeneous Effects on Regulated Firms by Industry**

Variables	ln(Output)				
	Baseline	Drop Power	Processing	Materials	Mining
Treat × Post	-0.204***	-0.206***	-0.219***	-0.153***	-0.251
	(0.042)	(0.042)	(0.073)	(0.053)	(0.275)
Observations	22,991	21,748	5,440	12,662	545
R^2	0.889	0.887	0.893	0.865	0.863
Firm FE	Y	Y	Y	Y	Y
Industry × Year FE	Y	Y	Y	Y	Y
Province × Year FE	Y	Y	Y	Y	Y

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Matching Related Data

Table: Matching Related Data with ASIF

Depth of Relation	Related Party Definition			
	Six level	Two Level		
% of Ownership	20%	20%	25%	51%
Registration Data	77,783	50,846	46,178	30,096
Reg. & ASIF	9,832	7,907	7,329	5,061
Reg. & ASIF (2-digit ind)	4,800	4,137	**3,992**	2,941
Reg. & ASIF (4-digit ind)	2,827	2,514	**2,466**	1,963

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Conglomerate Spillover: Baseline Results

Variables	ln(Output)			
Related × Post	0.152***	0.147***	0.118***	0.127***
	(0.037)	(0.037)	(0.037)	(0.035)
Observations	18,423	18,420	18,418	17,905
R^2	0.865	0.873	0.881	0.889
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry × Year FE		Y	Y	Y
Province × Year FE			Y	Y
Firm-level Controls				Y

▸ heterogeneity by ownership

Conglomerate Spillover by Firm Size

Variables	ln(Output)			
Related × Post(0%-30%)	0.104*	0.109**	0.048	0.078
	(0.054)	(0.052)	(0.052)	(0.051)
Related × Post(30%-60%)	0.130***	0.123***	0.096**	0.111**
	(0.047)	(0.045)	(0.046)	(0.043)
Related × Post(60%-100%)	0.164***	0.156***	0.161***	0.161***
	(0.045)	(0.044)	(0.043)	(0.040)
Observations	17,691	17,691	17,689	17,212
R^2	0.892	0.900	0.907	0.915
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry × Year FE		Y	Y	Y
Province × Year FE			Y	Y
Firm-level Controls				Y

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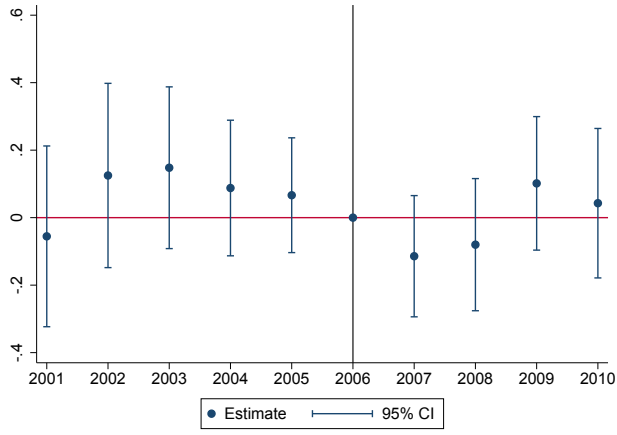
Conglomerate Spillover: Energy Efficiency



Data: Environmental Statistics Database

- Energy efficiency ↓ by $[-9\%, -6\%]$ (not significant) in related firms

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Conglomerate Spillover: Energy Efficiency

Variables	ln(Energy Efficiency)			
Related × Post	-0.077	-0.077	-0.059	-0.087
	(0.078)	(0.077)	(0.080)	(0.099)
Observations	3,724	3,722	3,668	2,801
R^2	0.866	0.870	0.880	0.867
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry × Year FE		Y	Y	Y
Province × Year FE			Y	Y
Firm-level Controls				Y

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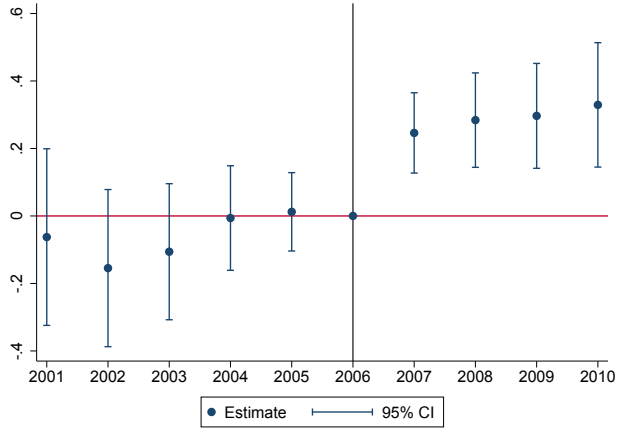
Conglomerate Spillover: Energy Use



Data: Environmental Statistics Database

- Energy use increases by $30 - 32\%$ in related firms

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Conglomerate Spillover: Energy Use

Variables	ln(Energy)			
Related × Post	0.322***	0.320***	0.302***	0.318***
	(0.075)	(0.073)	(0.076)	(0.094)
Observations	3,759	3,759	3,705	2,823
R^2	0.916	0.919	0.927	0.926
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry × Year FE		Y	Y	Y
Province × Year FE			Y	Y
Firm-level Controls				Y

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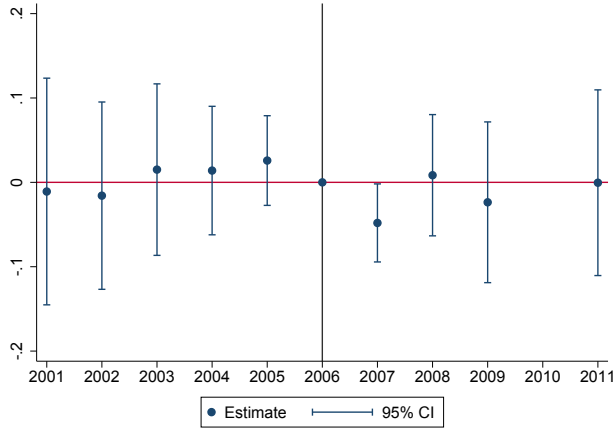
Placebo Test: Firms in Other Industries



Data: Survey of Industrial Firms

- No effect on related firms outside of 4-digit industries

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Placebo Test: Firms in Other Industries

Variables	ln(Output)			
Related × Post	-0.026	-0.025	-0.015	-0.003
	(0.040)	(0.039)	(0.039)	(0.038)
Observations	8,923	8,921	8,905	8,730
R^2	0.898	0.903	0.911	0.919
Firm FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Industry × Year FE		Y	Y	Y
Province × Year FE			Y	Y
Firm-level Controls				Y

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Conglomerate Spillover: Additional Results

Variables	ln(Sale)	ln(Profit)	ln(Capital)	ln(Labor)
Related × Post	0.115***	0.190***	0.102***	0.063**
	(0.033)	(0.055)	(0.035)	(0.026)
Observations	17,867	13,147	17,606	15,966
R^2	0.893	0.826	0.934	0.897
Firm FE	Y	Y	Y	Y
Industry × Year FE	Y	Y	Y	Y
Province × Year FE	Y	Y	Y	Y
Firm-level Controls	Y	Y	Y	Y

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Conglomerate Spillover by Type of Relation

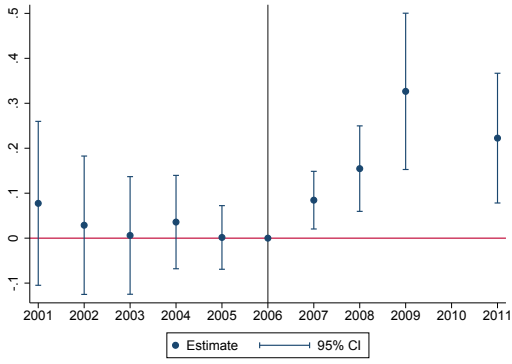

Figure: Investment

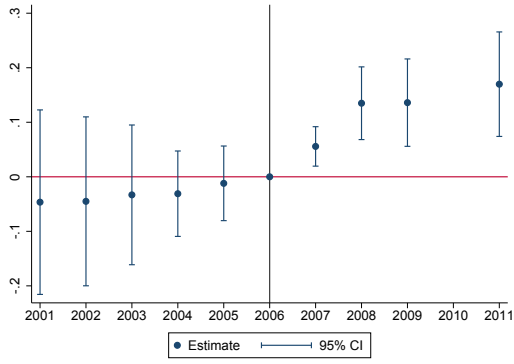

Figure: Shareholder Investment

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Conglomerate Spillover by Type of Relation

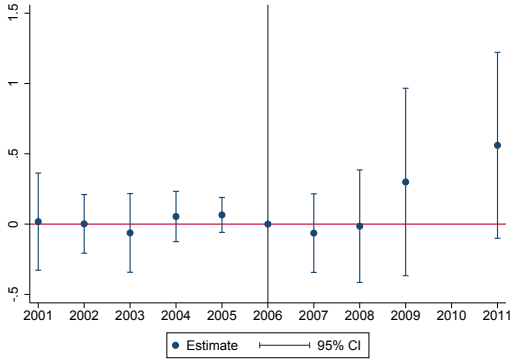

Figure: Affiliates

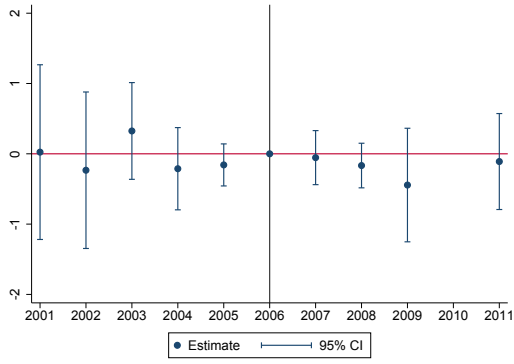

Figure: Shareholder

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Table: **Spillover Effects on Related Firms: Heterogeneous Effects by Industry**

Variables	ln(Output)				
	Baseline	Drop Power	Processing	Materials	Mining
Related × Post	0.118***	0.164***	0.105	0.180***	0.197**
	(0.037)	(0.040)	(0.096)	(0.056)	(0.080)
Observations	18,418	11,152	2,586	5,566	2,641
R^2	0.881	0.872	0.871	0.846	0.883
Firm FE	Y	Y	Y	Y	Y
Industry × Year FE	Y	Y	Y	Y	Y
Province × Year FE	Y	Y	Y	Y	Y

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Table: **Heterogeneous Spillover Effects by Location**

Variable	East&Mid to West	Within Region	West to East&Mid
Related × Post	0.117	0.164***	0.177
	(0.129)	(0.041)	(0.275)
Observations	1,133	9,230	456
R^2	0.900	0.887	0.907
Output Share	8.8%	83.4%	7.8%
Aggregate Effect	1.03%	13.7%	1.38%
Firm FE	Y	Y	Y
Industry × Year FE	Y	Y	Y
Province × Year FE	Y	Y	Y
Firm-level Controls	Y	Y	Y

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Market Equilibrium and Welfare

- Conglomerates operate whenever $\pi(\phi) \geq 0 \;\Rightarrow\; \phi \geq \phi_1 = \frac{(rf)^{\frac{1-\rho\alpha}{\rho}}}{R^{\frac{1-\rho}{\rho}} P C_\pi^{\frac{1-\rho\alpha}{\rho}}}$.
- Product market clearing $P = \left[\int_{\phi_1}^{\infty} p(\phi)^{1-\sigma} \frac{g(\phi)M}{1-G(\phi_1)} d\phi\right]^{\frac{1}{1-\sigma}} \qquad \sigma = \frac{1}{1-\rho}$
- Free entry given by: $\int_{\phi_1}^{\infty} \pi(\phi) g(\phi) d\phi - f_e = 0$.
- Welfare takes the form:

$$W = \left(\frac{R}{P}\right)^{1-\kappa} \left(\frac{1}{\beta E}\right)^{\kappa}$$

where the parameter κ captures the social welfare losses from emissions.

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Method of Moments Estimation

- We estimate the parameters $\theta = (\delta, f_e, \sigma_m)$:

$$\hat{\theta} = \arg \min_{\theta \in \Theta} [m_d - m(\theta)]' W [m_d - m(\theta)],$$

- m_d are the following data moments:
  1. share of firms in three bins of firm revenue:
     - 5-20 million RMB
     - 20-100 million RMB
     - $>$ 100 million RMB
  2. share of firm output in the same bins
  3. average relative output of the second, third, and fourth largest affiliates relative to the top firm in the conglomerate

- For θ, solve model and compute same moments: $m(\theta)$

- W is the identity matrix

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Model Estimates

Parameter		Value	Target
1. Fixed Values			
Elasticity of substitution	$\sigma = \frac{1}{1-\rho}$	4.00	Melitz and Redding (2015)
Returns to scale	α	0.90	Burnside et al. (1995)
Variable input share)	α_l	0.80	Cost share of variable inputs
2. Method of Moments			
Efficiency depreciation	δ	0.900	Within-conglomerate distribution
		(0.003)	
Dispersion of ln-ability ϕ	σ_m	1.239	Firm size distribution
		(0.055)	
Survival threshold	ϕ_1	0.609	Share of small firms
		(0.166)	

- Entry cost $f_e = 8.9$ million RMB (1.1. million USD) $\approx$ average profit in economy
- Per-firm registration cost of $f = 44,000$ RMB

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Equilibrium under Regulation

The equilibrium price level under the Top 1,000 regulation solves the following system of nonlinear equations:

$$\begin{aligned}\left(\frac{P}{P^*}\right)^{-\rho} &= (1-s_{\tilde{\phi}})\left(\frac{P}{P^*}\right)^{\frac{\alpha_l\rho^2}{1-\alpha_l\rho}} + s_{\tilde{\phi}}\mathbb{E}_e\left[\xi_q(\phi)^\rho \,\middle|\, \phi > \tilde{\phi}\right] \\ 1+\frac{\lambda(\phi)}{w+p_e} &= (\xi)^{\alpha_l-1}\left(\frac{P}{P^*}\right)^{\rho}\xi_q(\phi)^{\rho-1},\end{aligned}$$

where $s_{\tilde{\phi}}$ is the share of energy in regulated conglomerates prior to the regulation and $\mathbb{E}_e$ denotes the expectation with respect to the energy-use distribution from the unregulated equilibrium. Additionally, the aggregate change in energy use is given by

$$\frac{E}{E^*} = (1-s_{\tilde{\phi}})\left(\frac{P}{P^*}\right)^{\frac{\rho}{1-\alpha_l\rho}} + s_{\tilde{\phi}}\mathbb{E}_e\left[\xi_e(\phi)\,\middle|\,\phi > \tilde{\phi}\right].$$

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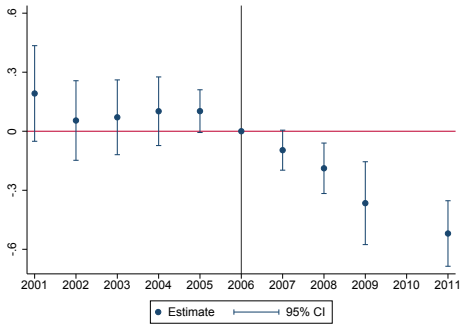
Within-Conglomerate Diff-in-Diff

Model links within-conglomerate Diff-in-Diff to λ_n:

$$\Delta_t(\ln q_1 - \ln q_i) = -\frac{\alpha_l}{1-\alpha_l} \ln\left[1 + \frac{\lambda(\phi)}{w + p_e}\right]$$



Data: Survey of Industrial Firms

- Treated: Top 1,000
  Control: Rest of conglomerate
- Includes conglomerate-year FEs
- $\beta \in [-37\%, -31\%]$
- Assuming $\alpha_l = 0.8 \Longrightarrow$

$$\frac{\lambda}{w + p_e} \in [8.1\%, 9.6\%]$$

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Pollution Damages

- Use four estimates of pollution damages:
  1. Mohan et al. (2020) estimate of Gross External Damage for China implies total pollution damages of $108 billion
  2. World Bank (2007) estimate total health costs from air pollution of $63 billion (Willingness-to-Pay) in 2003
  3. World Bank (2007) estimate total health costs from air pollution of $19 billion (Adjusted Human Capital) in 2003
  4. Ito and Zhang (2020) estimate based on Huai-River policy variation a Willness-to-Pay of $55.8 billion in 2013

- Compare estimates to total carbon emissions
  1. World Bank (2007) estimate implies pollution damage per ton of carbon= $4/$13
  2. Mohan et al. (2020) estimate implies pollution damage per ton of carbon= $17
  3. Ito and Zhang (2020) estimate implies pollution damage per ton of carbon= $7

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Pollution Damages

- More general welfare function allows for location-specific cost of pollution:

$$W = \left(\frac{R}{P}\right)^{1-\kappa} \left(\frac{1}{\beta_0 E}\right)^{\kappa_0} \prod_{n=1}^{N} \left(\frac{1}{\beta_1 E_n}\right)^{\lambda_n},$$

- The overall change in welfare is now:

$$\frac{d \ln W}{1-\kappa} = -\ln\left(\frac{P}{P^*}\right) - \frac{\kappa}{1-\kappa} \ln\left(\frac{E}{E^*}\right) - \sum_{n}^{N} \frac{\lambda_n}{1-\kappa} \left[\ln\left(\frac{E_n}{E_n^*}\right) - \ln\left(\frac{E}{E^*}\right)\right],$$

- Welfare depends on correlation between local pollution cost λ_n and local energy use $\ln\left(\frac{E_n}{E_n^*}\right)$

- But, we do not find larger output effects in more polluted or populated areas

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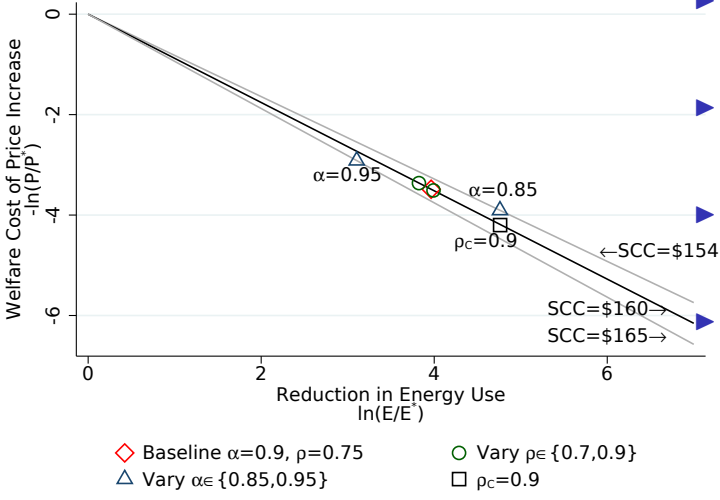
Table: **Heterogeneous Spillover Effects by Local Pollution and Density**

Variable	High to Low	Horizontal	Low to High
Related × Post	0.115**	0.101	0.224***
	(0.047)	(0.072)	(0.073)
Observations	10,256	3,740	3,457
R^2	0.895	0.883	0.897
Output Share	57.9%	13.9%	28.2%
Aggregate Effect	6.7%	1.4%	6.3%
Firm FE	Y	Y	Y
Year FE	Y	Y	Y
Industry × Year FE	Y	Y	Y
Province × Year FE	Y	Y	Y
Firm-level Controls	Y	Y	Y

Table: **Heterogeneous Spillover Effects by Location**

Variable	East&Mid to West	Within Region	West to East&Mid
Related × Post	0.117	0.164***	0.177
	(0.129)	(0.041)	(0.275)
Observations	1,133	9,230	456
R^2	0.900	0.887	0.907
Output Share	8.8%	83.4%	7.8%
Aggregate Effect	1.03%	13.7%	1.38%
Firm FE	Y	Y	Y
Industry × Year FE	Y	Y	Y
Province × Year FE	Y	Y	Y
Firm-level Controls	Y	Y	Y

Welfare Effects with Alternative Parameters



- Estimate (δ, σ, f, f_e) for different values of α, ρ
- Different ρs do not impact $GWTP$
- Higher α increases leakage but not $GWTP$
- Imperfect substitution within conglomerate $\rho_c < 1$ reduces leakage but not $GWTP$

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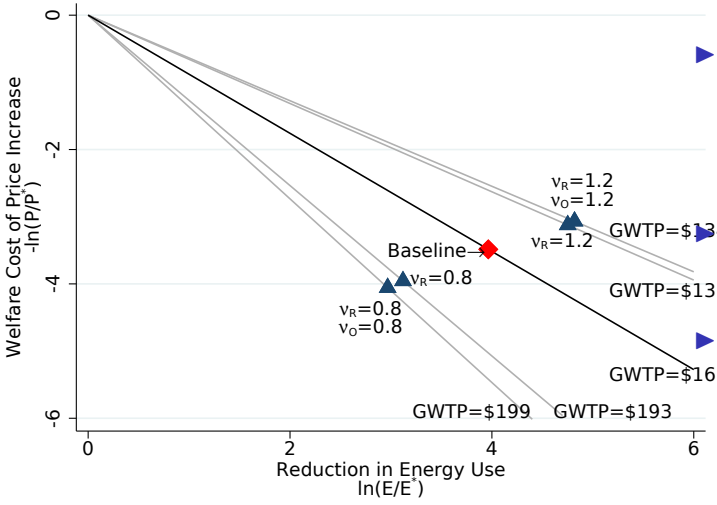
Welfare Effects with Heterogeneous Energy Efficiencies



- Leakage depends on relative energy efficiency of related ν_R and other firms ν_O
- Allow for differences of 20% in either direction
- $GWTP$ ranges between \$133 and \$197

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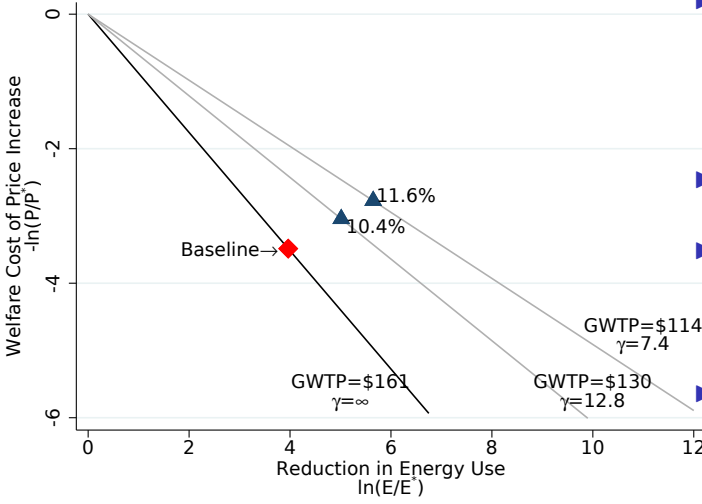
Welfare Effects with Endogenous Energy Efficiency



- Assume firms can improve energy efficiency with cost $c(\nu) = \nu^{\gamma}$
- Baseline model: $\gamma = \infty$
- Bound γ using upper 95% CI of effect on energy efficiency $\gamma = 7.4$
- Yields lower bound on $GWTP$ of \$112

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