Air Pollution and Manufacturing Firm Productivity: Nationwide Estimates for China

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Introduction

- Understanding cost of air pollution key to optimal regulation.
- Emerging literature focuses on labor productivity:
  - Graff Zivin and Neidell (AER, 2012): Fruit pickers in California.
  - Chang *et al*. (AEJ-Policy, 2016): Pear packers in California.
  - Chang *et al*. (AEJ-Applied, 2019): Call center staff in China.
  - He et al. (AEJ-Applied, 2019): Textile workers in China.
- However:
  - Focus on narrow groups of workers in particular occupations; external validity concern for broad-based environmental policies.
  - Only partial equilibrium analysis

Contributions

- Comprehensive, nationwide estimates:
  - All above-scale firms 1998 – 2007.
  - Over 90% of China's manufacturing output.
  - Find much larger impacts than previous studies (elasticity of -0.17)
  - A related paper by Dechezlepretre et al. on European regions
- First general-equilibrium analysis
  - Incorporate feedback from manufacturing output on pollution
  - Similar to Dynamic Integrated Climate-Economy (DICE) model (Nordhaus, Science 1992)
  - Effect is amplified to -0.31 considering the general equilibrium effect

Outline

- Introduction
- Partial equilibrium: Pollution on output
- General equilibrium
- Conclusion

Pollution on productivity

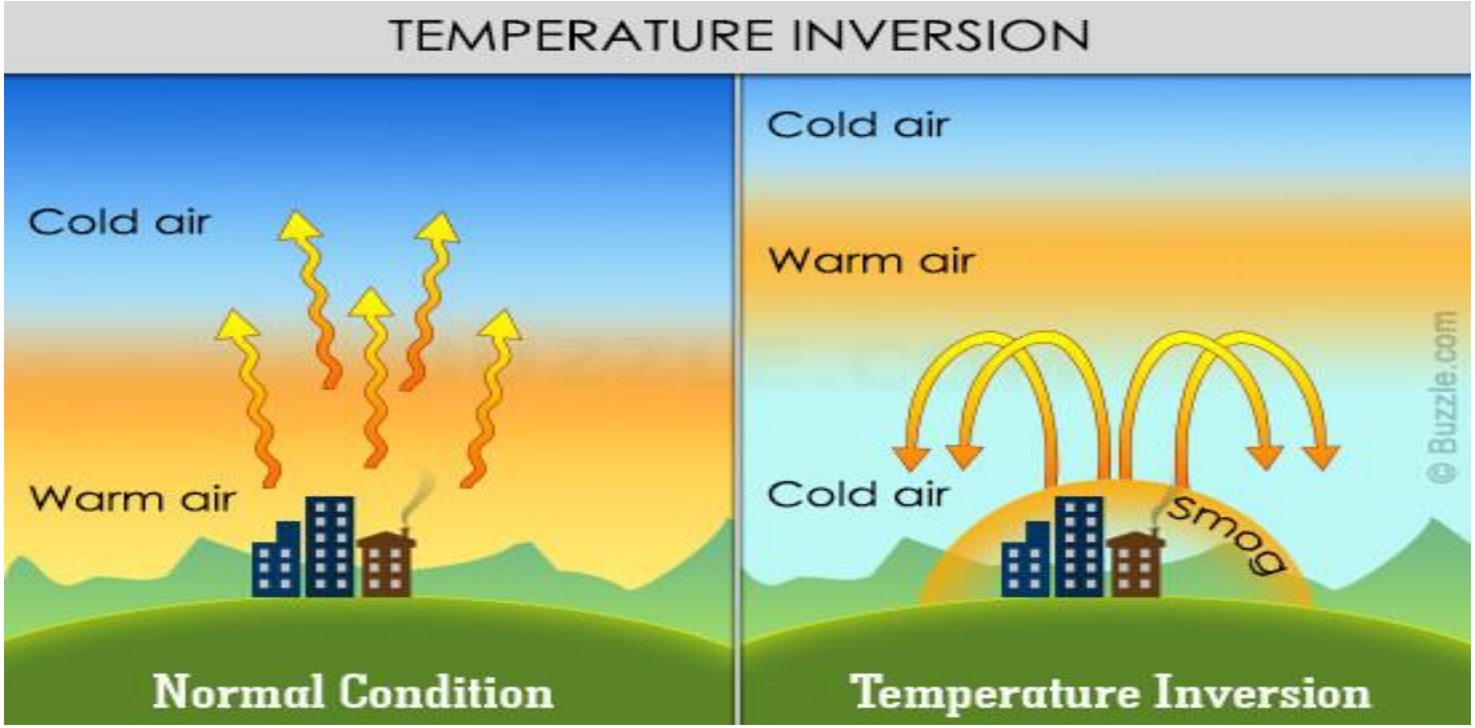
- $Productivity_{it} = \beta_0 + \beta_1 \Omega_{it} + \beta_2 W_{it} + \alpha_i + \rho_t + \varepsilon_{it}$:
  - i: firm; t: year.
  - Two measures of productivity: output per worker and TFP
  - Ω: $PM_{2.5.}$
  - W: weather controls.
  - α: firm fixed effects.
  - ρ: year fixed effects.
  - ε: firm-level unobserved productivity factors.

Identification Challenges

- Challenge 1: Simultaneity and omitted variables:
  - More output → more pollution (bias ↑).
  - Use of alternative inputs (bias ↑ or ↓).
  - Region-specific, time-varying correlation b/w output and pollution (bias ↑ or ↓).
- Challenge 2: spatial sorting:
  - Firms choose regions:
    - With better air quality (↓ bias).
    - With worse air quality: “pollution haven” effect (bias ↑ or ↓).
  - High-skilled workers more productive and willing to pay more for air quality (↓ bias).

IV Approach

- Use county-level thermal inversions as instrument (Arceo *et al*., 2016):
  - Meteorological phenomenon that increases pollution.
  - Conditional on weather, not a health risk.



Spatial Sorting

- Approach to firm spatial sorting:
  - Firm fixed effects absorb any initial sorting.
  - Firm sorting during sample period limited (7% change counties and robust to dropping).
  - Pollution not predictive of firm entry or exit.
- Approach to worker spatial sorting:
  - Firm fixed effects absorb any initial sorting.
  - Pollution not predictive of fraction of workers in high- versus low-technology firms.

Data (1)

- Sample period: 1998-2007.
- Productivity data (firm-year level):
  - Annual survey of manufacturers (NBS).
  - All SOEs, non-SOEs with revenues > CNY 5 million.
  - About 350 thousand firms and over 1.5 million observations.
  - Detailed balance-sheet data.
- $PM_{2.5}$ pollution data (county-year level):
  - Satellite-based (NASA).
  - Inferred from Aerosol Optimal Depth.
  - Resolution 50 x 60 km, convert to county.

Data (2)

- Thermal inversion data (county-year level):
  - Satellite-based temperature measure at 42 atmospheric layers each 6 hours (NASA).
  - Thermal inversion if temperature at 320 meters (2^{nd} layer) higher than at 110 meters (1^{st} layer).
  - Resolution 50 x 60km, convert to county.
  - Annual days with inversions.
- Merge pollution and inversion with firm data by county-year.

Table 2 OLS and 2SLS estimates (effect of air pollution on productivity) and reduced-form estimates (effect of thermal inversions on productivity)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS		**Reduced form**		**2SLS**			
					First stage			
Dependent variable:			**ln(Value added/worker)**		**$PM_{2.5}$**			
Annual days with inversions			-0.0002***	-0.0003***	0.0300***	0.0356***	0.0300***	0.0356***
			(0.0000)	(0.0001)	(0.0004)	(0.0004)	(0.0004)	(0.0004)
KP *F*-statistic					5,520	8,249	5,520	8,249
					Second stage			
Dependent variable:	**ln(Value added/worker)**				**ln(Value added/worker)**		**TFP (OP)**	**TFP (LP)**
$PM_{2.5}$	0.0003	0.0004**			-0.0080***	-0.0082***	-0.0049***	-0.0036***
	(0.0002)	(0.0002)			(0.0016)	(0.0014)	(0.0014)	(0.0014)
Firm fixed effects	Y	Y	Y	Y	Y	Y	Y	Y
Year fixed effects	Y	Y	Y	Y	Y	Y	Y	Y
Weather controls	N	Y	N	Y	N	Y	N	Y
# firms	356,179	356,179	356,179	356,179	356,179	356,179	356,179	356,179
Sample size	1,593,247	1,593,247	1,593,247	1,593,247	1,593,247	1,593,247	1,593,247	1,593,247

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Output on pollution

- $\Omega(t) = [\lambda(t)Q(t)]^{\mu(t)}$
- $\Omega(t)$-$PM_{2.5}$
- $\lambda(t)$-Fraction of total output produced by manufacturing sector
- $\mu(t)$-Elasticity of pollution with respect to output
  - Using China joined the WTO as the IV
  - DID (coastal vs inland regions; before and after)

Appendix 13: OLS and 2SLS estimates (effect of output on pollution) using effect of China joining WTO on coastal versus inner regions as an instrument

	(1)	(2)
	OLS	**2SLS**
		First stage
Dependent variable:		**ln(Value added)**
Coast*post 2001		0.0574***
		(0.0147)
KP *F*-statistic		15.3
		Second stage
Dependent variable:	**$\ln(PM_{2.5})$**	
ln(Value added)	0.0048***	1.4317***
	(0.0012)	(0.3666)
County fixed effects	Y	Y
Year fixed effects	Y	Y
Sample size	25,357	25,357

General equilibrium

- $\max_{c(t)} \sum_{t=1}^{T} P(t) ln[c(t)](1+\rho)^{-t}$
- $Q(t) = \Omega(t)^{\theta} A(t) K(t)^{\gamma} P(t)^{1-\gamma}$,
- $\Omega(t)^{\theta}$-how pollution affects output
- $\Omega(t) = [\lambda(t) Q(t)]^{\mu(t)}$-how output affects pollution
- $Q(t) = C(t) + I(t)$
- $K(t) = (1-\delta)K(t-1) + I(t)$

General equilibrium

- A 1% decrease in $PM_{2.5}$ increases manufacturing output by 0.31%, or 0.043% of China's GDP
- Partial equilibrium is 0.17%
- Intuition: decreased output results in somewhat less pollution and thus somewhat more output
- Important for policy evaluations

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Contact

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