Air Pollution and Student Performance in the U.S

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Motivation

- Accounting for the external costs of air pollution
  - Negative effects on health, worker productivity, crime
- Adverse effects of pollution on student learning
- Low-income families more likely to live in polluted areas (Currie et al., 2020)
- Recently, substantial decreases in pollution in the United States
  - Clean Air Act
  - Last decade: decline in coal usage with fall in natural gas prices

Research Question

- New data and methods: quantify effect of particulate pollution on student test scores at the school district level
    - IV strategies using variation in pollution from power plants
    - Unique data that allows us to control for moving rates (district - year)
- Estimate how the Black-White test score gap has narrowed as a result of falling pollution

Related Literature

- **Air Pollution and Education:** Ebenstein et al. (2016), Persico and Venator (2021), Duque and Gilraine (2020), Heissel et al. (2020), Mullen et al. (2020), Marcotte (2017)
- **Air Pollution and Inequality:** Currie et al. (2020), Chay and Greenstone (2003)

Pollution from PM2.5

- Focus on PM2.5 : fine particulate matter measuring less than 2.5 microns
- Small size of particles $\rightarrow$ travel deep into lungs and reach the bloodstream (CDC, 2019)
- Exposure to PM2.5: throat and lung irritation, worsen respiratory disease (asthma) and cardiovascular disease
- Evidence points to PM2.5 also directly affecting cognitive performance (Shehab and Pope, 2019)

Data

- Time period: 2008-09 to 2017-18
- Stanford Education Data Archive: district-grade-subject-year test scores, demographics (Reardon et al., 2021)
- Pollution: month-district PM2.5 levels from Van Donkelaar et al. (2009), averaged over school year
- Energy Production: lat/lon, school year production, fuel type (EIA)
- Controls: economic conditions (ACS 5-year), weather (NOAA), moving rates by district and year (Infutor)
    - Residential locations of over 80 million Americans aged 18-50

Methodology: OLS

$$y_{s,d,c,t} = \alpha + \beta PM2.5_{d,t} + \gamma X_{s,d,c,t} + \eta W_{d,t} + \omega_s + \theta_d + \phi_c + \nu_t + \epsilon_{s,d,c,t} \tag{1}$$

- $s = subject, d = district, c = cohort, t = year$
- $\gamma X_{s,d,c,t}$: student demographics
- $W_{d,t}$: district moving and economic controls
- Endogeneity: $PM2.5_{d,t}$ measured with error and possibly correlated with sorting
    - Diao et al. (2019), Richmond-Bryant and Long (2020), Dahl and Lochner (2012)

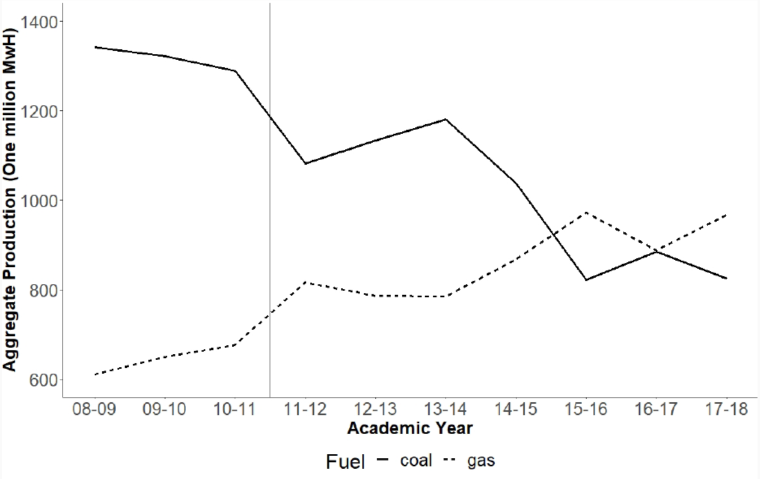
Methodology: Distance to Coal Plants IV

- IV: Instrument for district PM2.5 exposure with yearly production from coal power plants up to 60km away
- PM2.5 from coal does not travel $\geq$ 50km (Levy et al. 2002, Clay et al. 2016)
- Power plants generate 30% of particulate matter pollution in the U.S. (McDuffie et al., 2021)

Methodology: Distance to Coal Plants IV

- Year-to-year production variation in coal production
- Guards against bias from individuals moving: sorting must be driven by students moving in response to production changes (unlikely)
- Also test by using separate instruments for production within 0-20km, 20-40km, 40-60km
    - Expect that local economic effects of plant closures should be concentrated close to the plant

U.S. Coal and Gas Production



Total coal (solid line) and natural gas (dashed line) electricity production in the United States from academic years 2008-09 to 2017-18.Source: U.S. EIA

Methodology: Shift-Share IV

- Energy production in the U.S. has shifted over past decade: coal to natural gas (esp. in 2011-12)
- Natural gas emits less particulates $\rightarrow$ improvement in air quality
- Shift-Share IV: interact pre-existing shares for coal, oil, gas, renewables with annual aggregate growth in each source

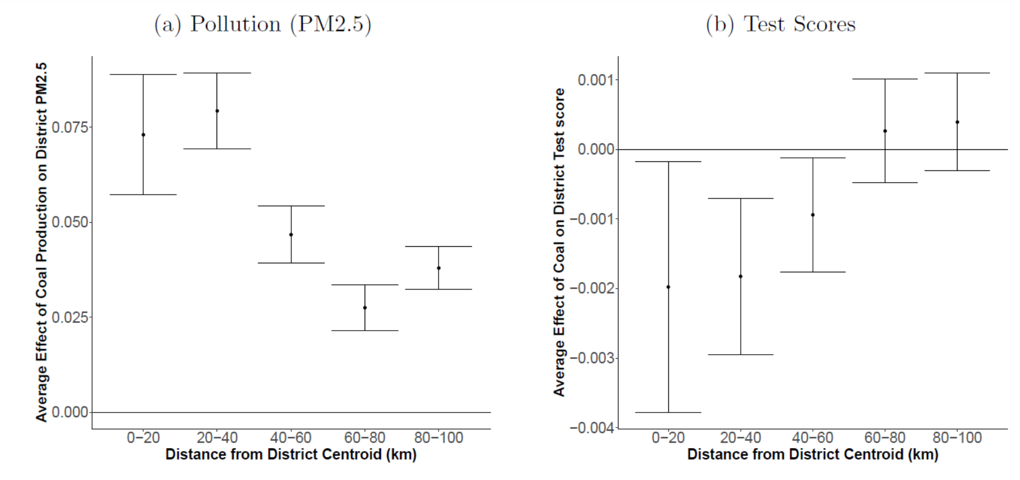
$$\sum_{f} \delta_{2005,f,d} \Gamma_{t,f} \tag{2}$$

- $\delta_{2005,f,d}$ is the share of district d's 2004-05 fuel production within 40km of its centroid from source $f \in \{\textit{coal, gas, oil, renewables}\}$
- $\Gamma_{t,f}$ is the growth rate of fuel f in year t

Methodology: Shift-Share IV

- District controls are from 2004-05 interacted with year fixed effects
    - Guards against fuel shifts affecting demographics
- Validity: Rotemberg weights for each fuel source (Goldsmith-Pinkham et al. 2020)
    - Coal production has the highest weight at 0.5
- Limited correlation between 2004-05 fuel shares and the moving and demographic controls

Results: Distance to Coal Plants

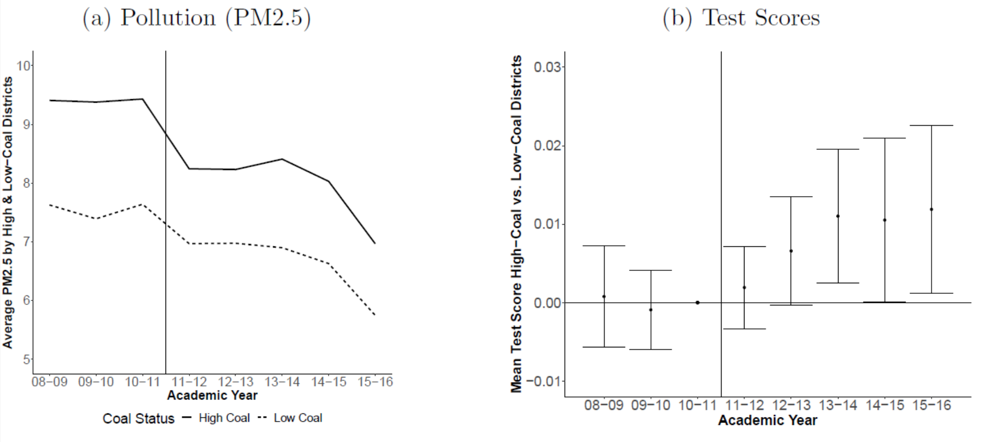


(a) Effect of Coal Production (Million MwH) on district PM2.5 by coal plant distance. (b) Effect of Coal Production (Million MwH) on district test scores by coal plant distance

Shift-Share Results: Diff-in-Diff

- Validity: differential effect of higher exposure of one power producing industry only affects the change in test scores through air pollution
- Recast as diff-in-diff:
  - Compare districts that are exposed to high vs. low coal production before and after the drop in aggregate coal in 2011-12
  - Based on 2004-05 coal production that took place within 40km of a district's centroid.

Shift-Share: Diff-in-Diff



(a) Average PM2.5 by High vs. Low-Coal Districts (b) Average Test score by High vs. Low-Coal Districts

Results: Effect of Pollution on Test Scores

Outcome: Standardized Test Scores	(1)	(2)	(3)	(4)
Panel A: Empirical Strategy I: Distance and Production Variation				
IV Estimate	−0.0198***	−0.0198***	−0.0204***	−0.0206***
($\mu g/m^3$)	(0.0042)	(0.0042)	(0.0045)	(0.0045)
First-Stage F-stat	203.92	202.15	191.48	191.39
Observations	701,199	694,257	694,257	694,257
Panel B: Empirical Strategy II: Shift-Share Instrument				
IV PM2.5 Estimate	−0.0176***	−0.0206***	−0.0181**	−0.0165**
($\mu g/m^3$)	(0.0050)	(0.0064)	(0.0071)	(0.0069)
First-Stage F-stat	662.08	408.31	377.40	390.53
Observations	607,482	604,232	604,232	604,193
Controls Used:				
Student Covariates	Yes	Yes	Yes	Yes
Local Economic Controls	No	Yes	Yes	Yes
Weather Controls	No	No	Yes	Yes
Sorting Controls	No	No	No	Yes

Pollution and Test Score Gap

Academic Year	2002-03	2010-11	2018-19	Change from 2002-03 to 2018-19
Panel A. Mean PM2.5 Exposure				
Average PM2.5 Exposure	10.47	8.72	7.47	-3.00
Panel B. Black-White Exposure Gap				
Black PM2.5 Exposure	11.51	9.60	8.10	-3.41
White PM2.5 Exposure	9.83	8.32	6.92	-2.91
Black-White PM2.5 Gap	**1.68**	**1.28**	**1.18**	**-0.50**
Panel C. Black-White Test Score Gap				
Black Mean Test Score	-0.61	-0.51	-0.47	0.14
White Mean Test Score	0.29	0.28	0.25	-0.04
Black-White Test Score Gap	**0.90**	**0.79**	**0.72**	**-0.18**

Robustness Checks

- Shift-Share: 2000-01 production, 60km distance from district
- Distance to coal: separate distance IVs
- States that test only in spring vs. all year

Conclusion

- Air pollution significantly lowers student test scores.
- Large $3\mu g/m^3$ drop in PM2.5 concentrations experienced by the average student raised test scores nationwide.
- Counterfactual: Decreasing average PM2.5 to that of the first quartile district $\rightarrow$ nationwide test scores increase by 0.036
- Eliminating Black-White differences in particulate exposure:
  - Decrease the Black-White test score gap by 0.024 s.d.