Quantifying the Impact of Pollution Exposure on Academic Achievement in California

A Culminating Research Project by

Michael Turgeon

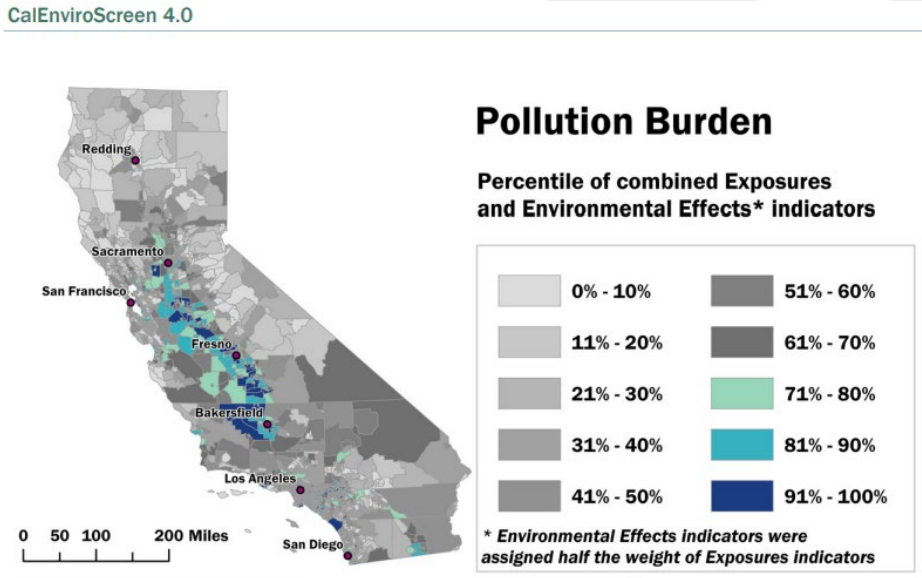
California State University, Sacramento
Department of Public Policy and Administration

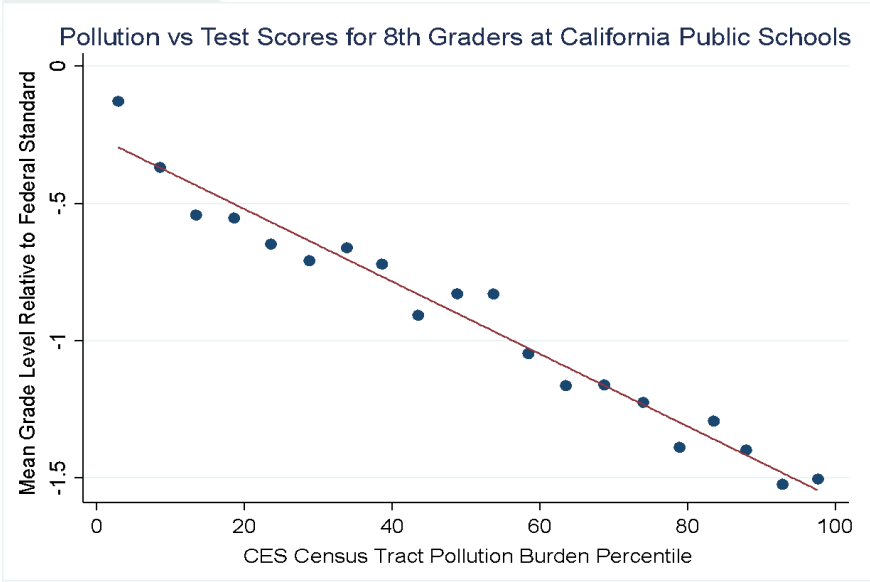
March 6, 2023

SACRAMENTO STATE
Redefine the Possible

Quantifying the Impact of Pollution Exposure on Academic Achievement in California

Pollution and Test Scores: A Clear Pattern Tied to Socioeconomic Disparities





SACRAMENTO STATE
Redefine the Possible

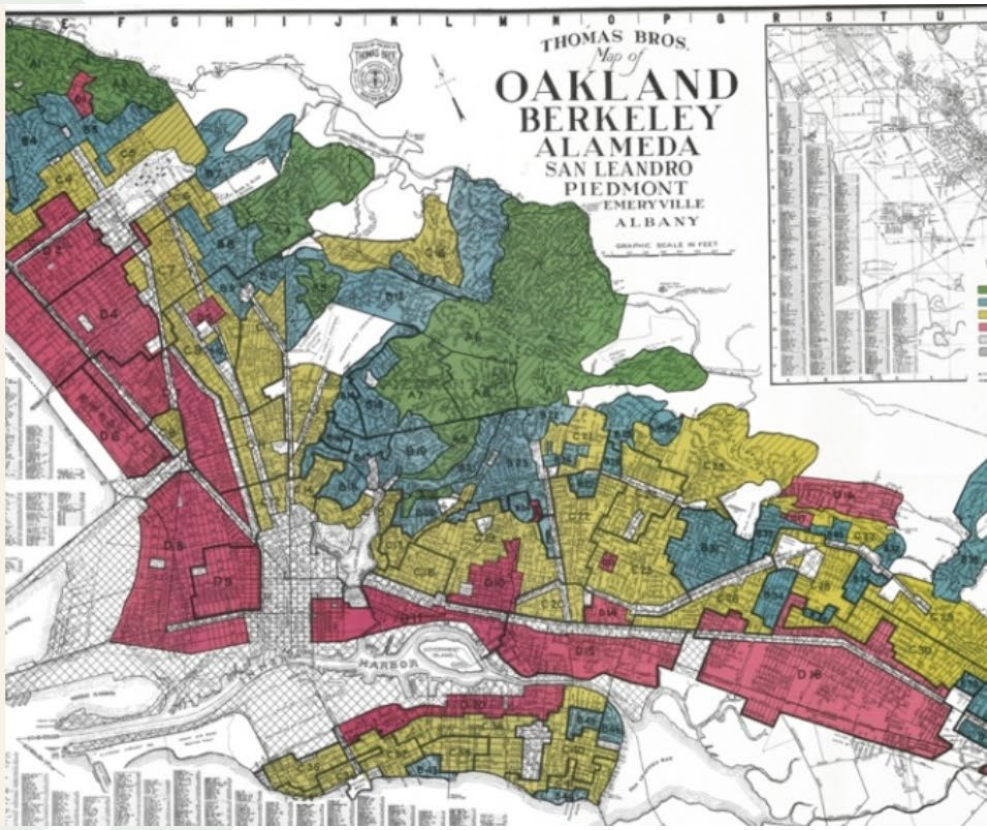
Quantifying the Impact of Pollution Exposure on Academic Achievement in California

Pollution and Prejudice

Redlining and Environmental Injustice in California

CalEPA

August 16, 2021



SACRAMENTO STATE

Redefine the Possible

Quantifying the Impact of Pollution Exposure on Academic Achievement in California

Research Question

- What is the impact of childhood exposure to various pollution sources on average school district standardized test scores in California, after controlling for confounding factors?

Quantifying the Impact of Pollution Exposure on Academic Achievement in California

Causal Mechanisms and Prior Research

- Ambient air pollution can cause chronic respiratory conditions like asthma that lead to school absences
- Air pollution can also cause direct cognitive impairment
- Toxic heavy metals in the air or water can irreparably harm brain development
- A few studies have compared air pollution to test scores over different time horizons, but leave unanswered questions
- Prior studies have not examined this connection for many other pollution variables

Quantifying the Impact of Pollution Exposure on Academic Achievement in California

My Methodological Approach

- Test score data for CA 6th graders in reading and math from 2009-2018 from Stanford Education Data Archive
- Pollution data from three iterations of CalEnviroScreen
  - *Pollution variables used*: Fine Particulate Matter (PM 2.5), Traffic, Solid Waste Facilities, Toxic Cleanup Sites, Hazardous Waste Facilities, Groundwater Threats, Impaired Water Bodies
- GIS mapping connects schools to census tracts for assigning pollution scores and producing district averages
- I apply a "fixed effects" panel regression model to capture a holistic picture of test score variance, control for confounding factors, and estimate the impact of pollution variables

Quantifying the Impact of Pollution Exposure on Academic Achievement in California

Primary Results

Table 2: Regression Results from the Preferred Specification[a]. From top to bottom, each cell includes 1) elasticity at the mean, 2) the regression coefficient, and 3) the robust standard error. Results for the included control variables are found in Table A3. *** p<0.01, ** p<0.05, * p<0.1.

Significant Pollution Variables	Average Scores	Math	ELA	Average Scores	Math	ELA	Average Scores	Math	ELA
PM 2.5	-0.043 -0.00457** (0.00213)	-0.0024 -0.000255 (0.00426)	-0.085 -0.00897*** (0.00247)						
Groundwater Threats				-0.0055 -0.000197** (8.12e-05)	-0.0067 -0.000240** (0.000100)	-0.0044 -0.000157* (8.12e-05)			
Solid Waste Facilities							-0.011 -0.00338** (0.00146)	-0.013 -0.00392** (0.00164)	-0.0095 -0.00285 (0.00204)
Constant	1.681*** (0.0640)	1.581*** (0.0859)	1.783*** (0.0635)	1.637*** (0.0634)	1.575*** (0.0775)	1.703*** (0.0642)	1.641*** (0.0631)	1.579*** (0.0776)	1.706*** (0.0641)
Error Clustering Level	Commute Zone	Commute Zone	Commute Zone	Commute Zone	Commute Zone	Commute Zone	Commute Zone	Commute Zone	Commute Zone
Observations	10,964	5,486	5,478	11,554	5,782	5,772	11,554	5,782	5,772
N districts	712	710	711	723	720	722	723	720	722
R^2 (within districts; between district; overall)[b]	0.047; 0.490; 0.495	0.032; 0.536; 0.553	0.112; 0.299; 0.289	0.038; 0.511; 0.482	0.028; 0.569; 0.537	0.086; 0.301; 0.264	0.038; 0.497; 0.474	0.028; 0.552; 0.526	0.087; 0.301; 0.266

[a]For the Preferred specification, the dependent variable is natural log of grade levels (the GCS scale) and I inputted each pollution variable one at a time (i.e., each regression coefficient represents a separate regression trial). I did include four other pollution variables in my model (Traffic, Cleanup Sites, Hazardous Waste Facilities, and Impaired Water Bodies) but found they were not significant for either test subject and thus omitted them from this table.

[b]R^2 for the fixed effects panel regression trials is reported as the percent of variation in test scores either within or between school districts accounted for by the model inputs, with the "overall" R^2 calculated as the weighted average of the two. It does *not* represent the proportion of *total* test score variation across all observations accounted for by the suite of explanatory variables and fixed effects, which for all trials was approximately 0.9.

Quantifying the Impact of Pollution Exposure on Academic Achievement in California

Other Findings

- Effect of PM 2.5 clearly varies across discrete quintiles of ambient concentration
- Quintile effect not detectable for Groundwater Threats and Solid Waste Facilities
- Also tested interaction between PM 2.5 and geography, since constituent particulates theoretically vary in toxicity (found no difference between urban and rural)
- Four other pollution variables tested produced no detectable effects

Quantifying the Impact of Pollution Exposure on Academic Achievement in California

Effect Size Analysis

- After robustness tests, most confident findings are effects of: 1) PM 2.5 on reading, 2) Solid Waste Facilities on math, and 3) Groundwater Threats on math.
- Using standard deviations (st. dev.) to compare effect size across variables with different units:
  - *One st. dev. increase in PM 2.5 = 2.8% decrease in reading scores*
  - *One st. dev. increase in Groundwater Threats = 1.0% decrease in math*
  - *One st. dev. Increase in Solid Waste Facilities = 1.8% decrease in math*
- Effect size found for PM 2.5 aligns with prior studies

Quantifying the Impact of Pollution Exposure on Academic Achievement in California

Policy Implications

- Some back-of-the-envelope calculations:
  - Installing and maintaining plug-in air purifiers in classrooms costs ~$1,000 per-class, per-year and boosts long-run average test scores by ~0.1-0.2 standard deviations
  - Reducing class sizes by 10 students results in a similar magnitude of test score benefit, but costs ~$1,300 *per-student*
  - With a class size of 20 students, air filtration is ~26x more cost-effective than class size reductions for test score improvements
- Implications for district budgets and the cost-benefit analysis of environmental regulations; equitable distribution of benefits
- *Ideas for legislation*: state-sponsored pilot programs; indoor air quality standards for schools and public buildings

Quantifying the Impact of Pollution Exposure on Academic Achievement in California

Remaining Questions

- What causal mechanisms account for the effects of Groundwater Threats and Solid Waste Facilities?
- Why were the results so different for math vs reading?
- How much of the effect of PM 2.5 is through respiratory illness versus cognitive impairment?

Future research is also needed to explore:

- The effects of other pollutants I did not include (pesticides, industrial toxins, various sources of lead)
- The effect of pollution on lifetime earnings, which influences academic outcomes in subsequent generations

Quantifying the Impact of Pollution Exposure on Academic Achievement in California

Final Considerations

- Pollution exposure and test scores to some extent are endogenous, with a causal direction that is circular
- These results are likely *underestimates* of the true impact of holistic pollution exposure on education and economic opportunity, as disparities compound generationally
- Pollution mitigation is an antiracist policy that works to address academic and economic disparities tied to historic land-use discrimination