Lecture 17: The Clean Air Act

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Environmental Economics
Econ 4075

Roadmap

Topics on the Clean Air Act:

- Motivation
- Four Provisions of the CAA
- Amending the CAA
- Economics of the CAA

Why Regulate Air Quality?

Why did the U.S. government regulate air quality?

- Growing consciousness of environmental issues.
- Costs of air pollution.
- Cross-boundary pollution and the "race to the bottom."
  - Competition to decrease regulations to attract firms.
  - Free riding by specific jurisdictions if improvements.
  - Lack of coordination by states increases uncertainty and costs of regulation for firms.

"Dirty Air"

Created with DALL-E.

Background on the CAA

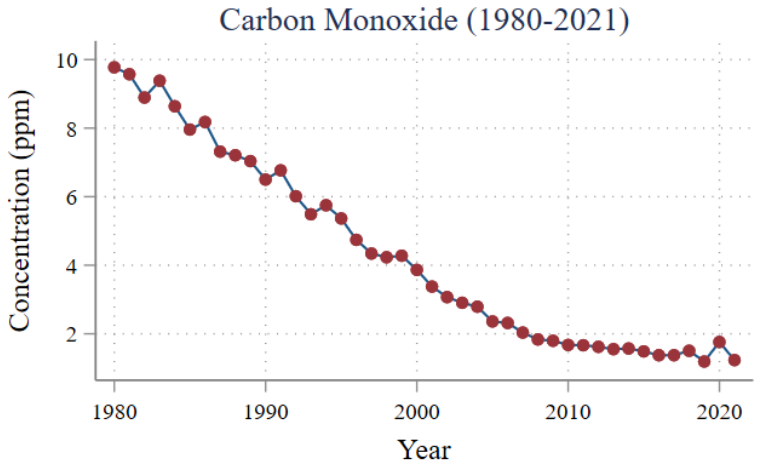
The 1970 Clean Air Act (CAA) passed after the first celebration of Earth Day and the creation of the Environmental Protection Agency.

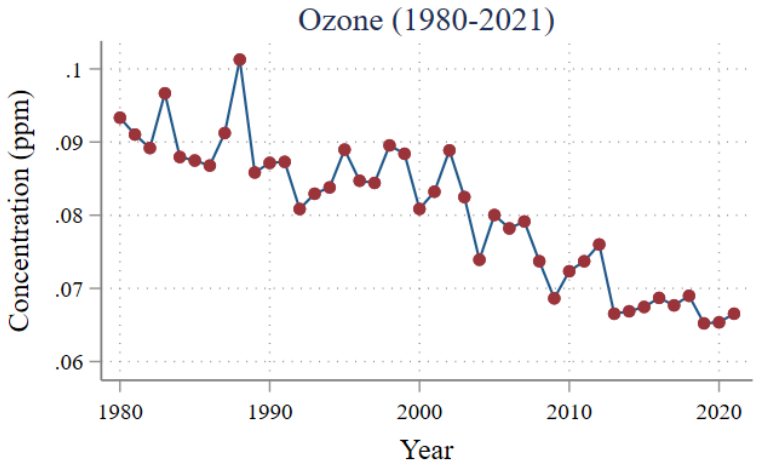
- Goal: “protect and enhance the quality of the Nation’s air resources so as to promote the public health and welfare and the productive capacity of its population.”
- The bill had unanimous support in the Senate and one dissenting vote in the House.
- Aside: The National Bureau of Economic Research didn’t hold its first environmental seminar series until 1991.

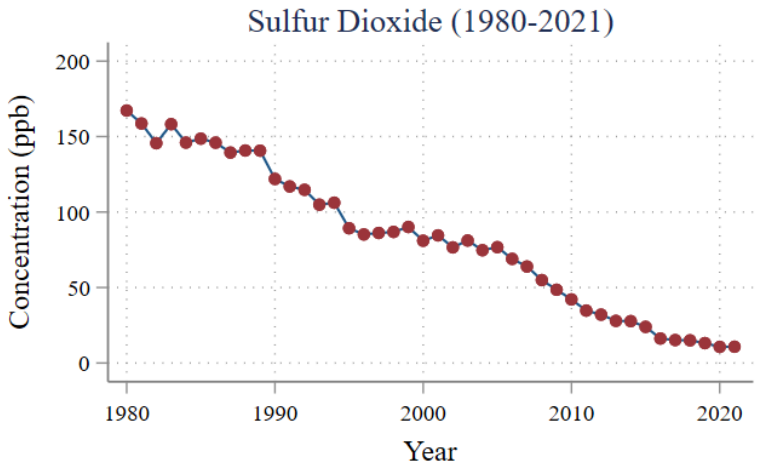
Why should we care about the CAA?

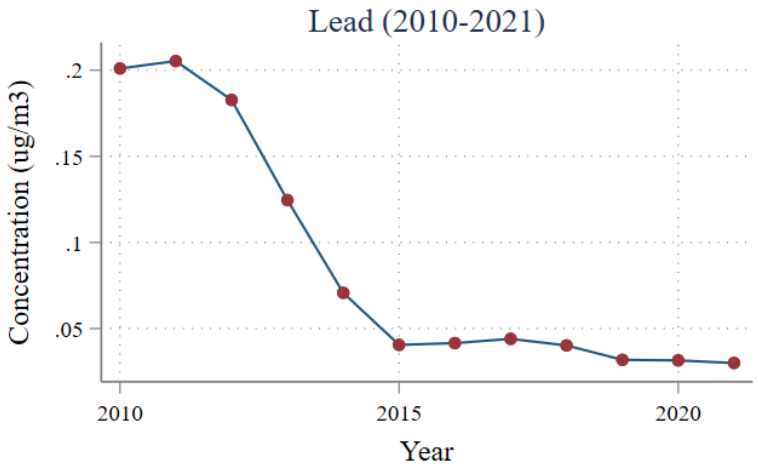
The Clean Air Act explains a large share of long-term decreases in air pollution (Shapiro, 2021).

From 2003-2012, reductions of *just* PM 2.5 accounted for **one third to over half of the benefits of *ALL* significant federal regulations** (Dominici, Greenstone, Sunstein, 2014).









Source: https://www.epa.gov/air-trends

Part 1: Four Provisions of the Clean Air Act

Four Provisions of the Clean Air Act

The 1970 Clean Air Act charged EPA with administering four provisions of the new law.

1) Promulgate **National Ambient Air Quality Standards** (NAAQS)
2) Approve **State Implementation Plans** (SIPs)
3) Develop **New Source Performance Standards** (NSPS)
4) Develop **National Emission Standards for Hazardous Air Pollutants** (NESHAPs)

National Ambient Air Quality Standards (NAAQS)

Key facts on the National Ambient Air Quality Standards (NAAQS):

- Six **criteria pollutants** were identified as ubiquitous, created by diverse sources, and with adverse effects on public health *or* welfare.
  - These pollutants are carbon monoxide, lead, ground-level ozone, nitrogen dioxide, particulate matter, and sulfur dioxide.
- EPA sets primary and secondary standards for these chemicals over specific time horizons. Standards are based on safety and welfare impacts.
- Legally, EPA is not allowed to consider costs of control when setting NAAQS.

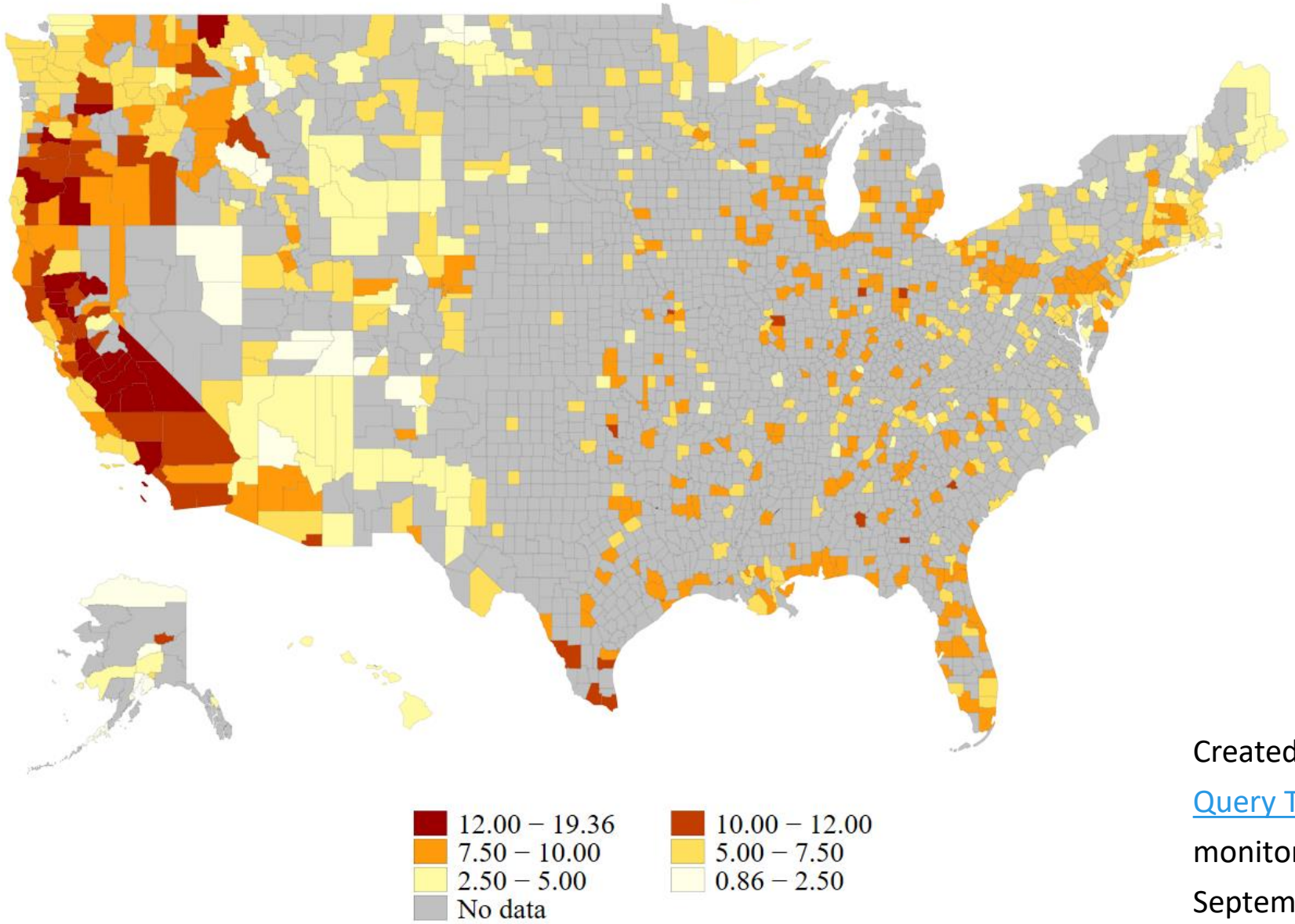
National Ambient Air Quality Standards (NAAQS)

- **Primary standards** are limits set to protect human health, especially for susceptible individuals (e.g., those with asthma).
- **Secondary standards** are based on welfare impacts (e.g., crop damage).

Pollutant		Primary/ Secondary	Averaging Time	Level
Carbon Monoxide (CO)		primary	8 hours	9 ppm
			1 hour	35 ppm
Lead (Pb)		primary and secondary	Rolling 3 month average	0.15 µg/m3 (1)
Nitrogen Dioxide (NO2)		primary	1 hour	100 ppb
		primary and secondary	1 year	53 ppb (2)
Ozone (O3)		primary and secondary	8 hours	0.070 ppm (3)
Particle Pollution (PM)	PM2.5	primary	1 year	12.0 µg/m3
		secondary	1 year	15.0 µg/m3
		primary and secondary	24 hours	35 µg/m3
	PM10	primary and secondary	24 hours	150 µg/m3
Sulfur Dioxide (SO2)		primary	1 hour	75 ppb (4)
		secondary	3 hours	0.5 ppm

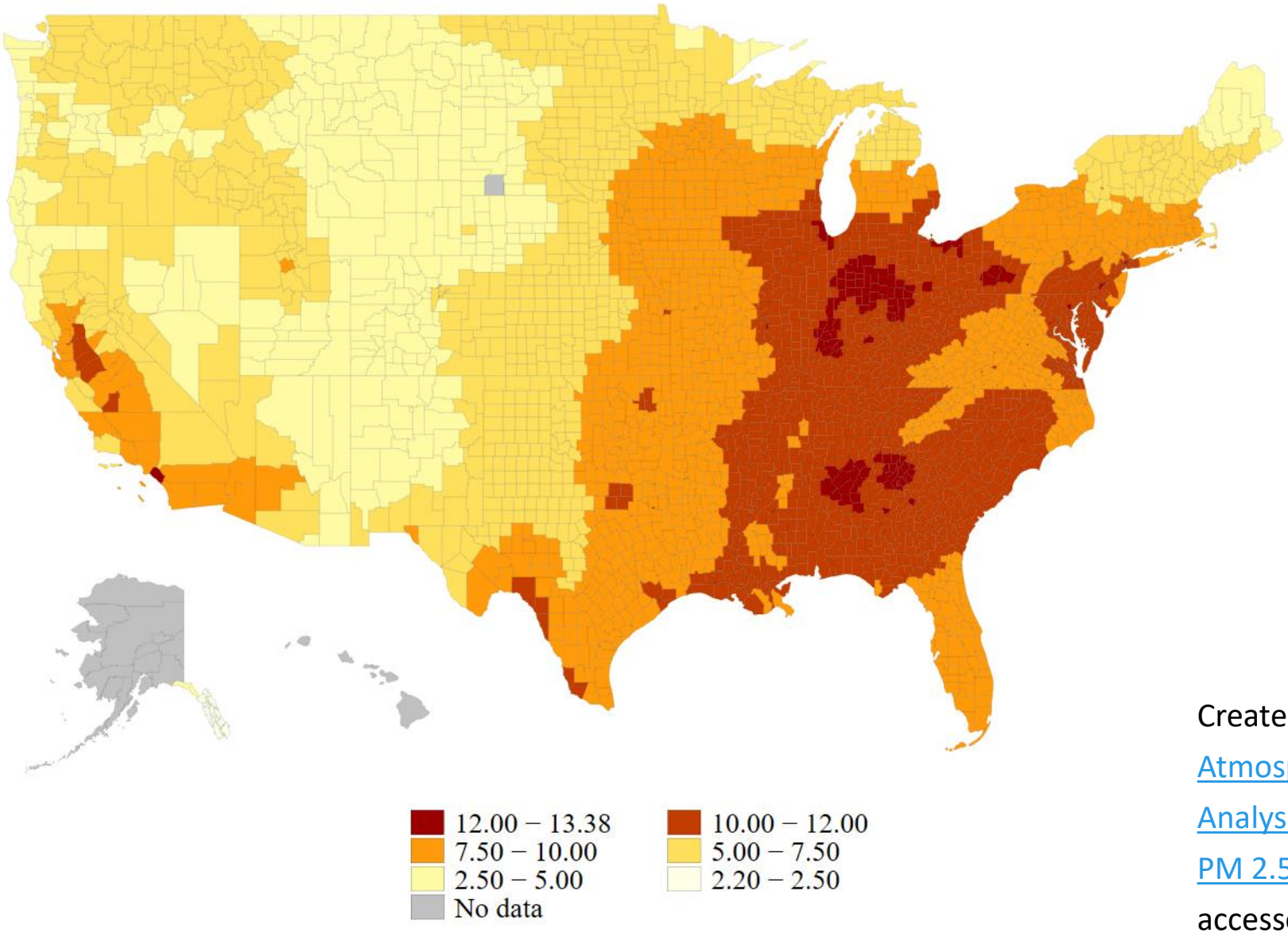
For more information, see https://www.epa.gov/criteria-air-pollutants/naaqs-table

Daily Average PM 2.5 Concentration (ug/m3) in U.S. Counties (2020)

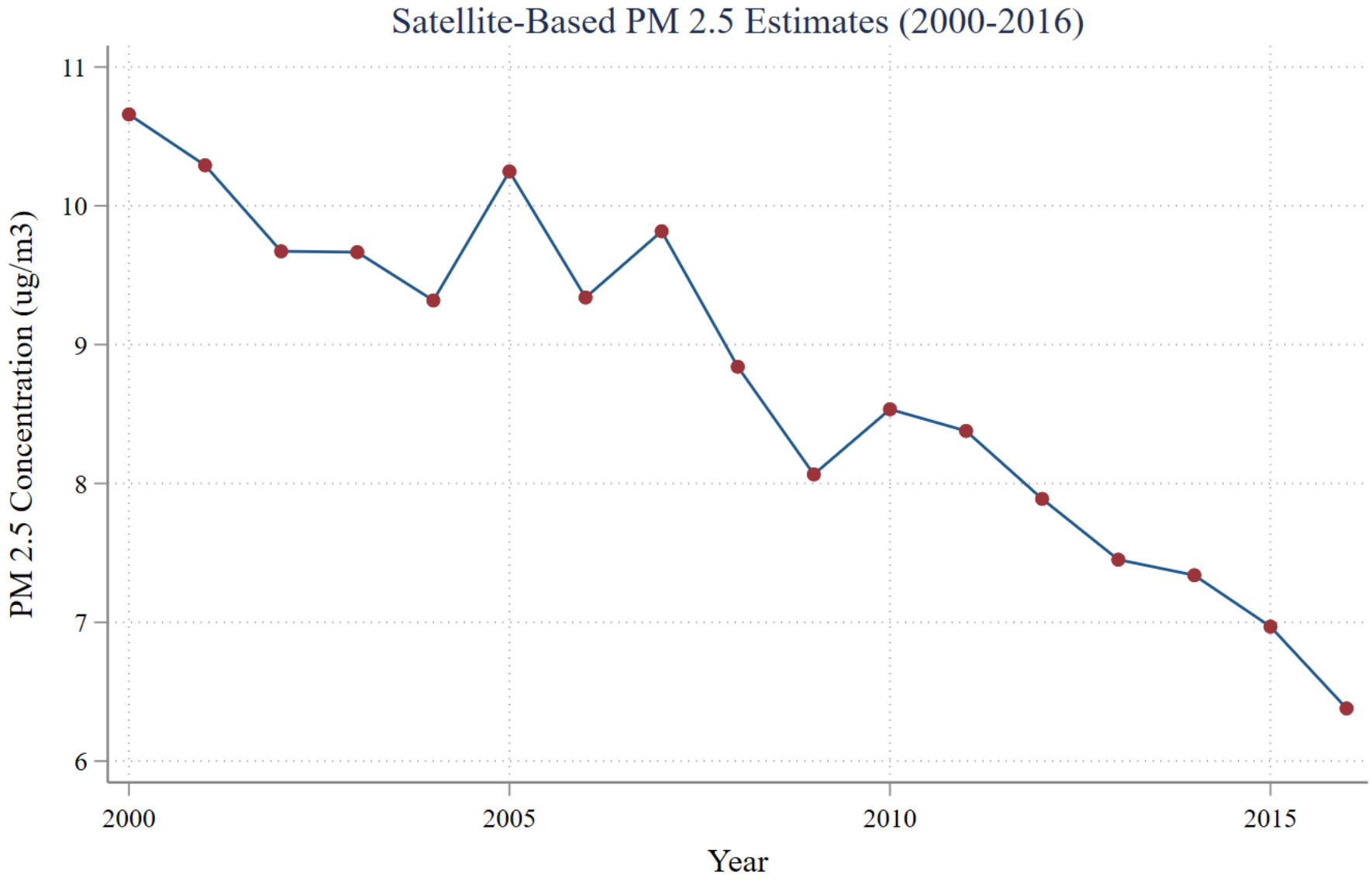


Created using EPA's AirNow Query Tool of air quality monitor data. Last accessed September, 2021.

Average PM 2.5 Concentration (ug/m3) in U.S. Counties (2000-2016)



Created by extracting Atmospheric Composition Analysis Group Satellite-Based PM 2.5 Estimates. Last accessed August, 2020.



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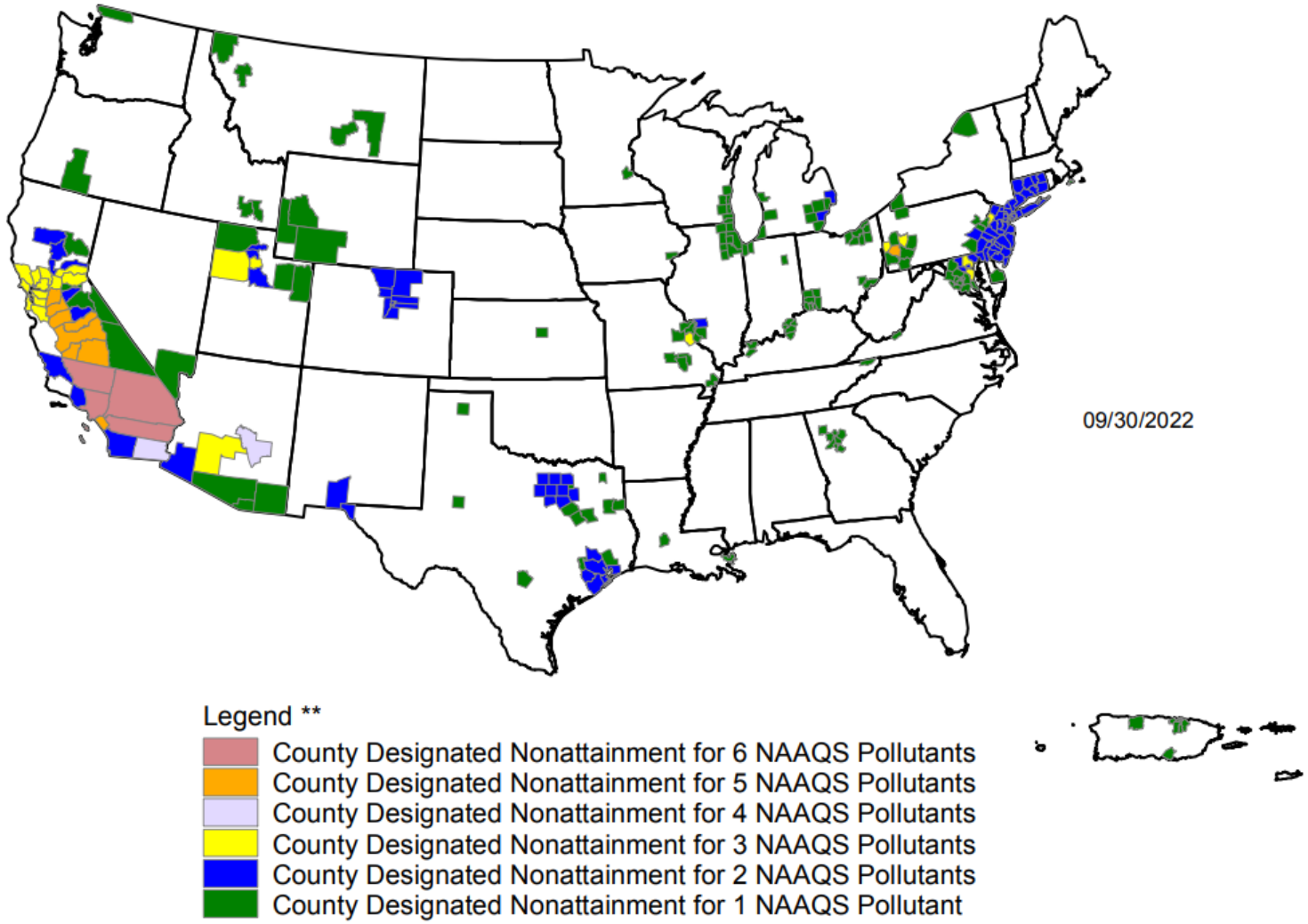
Non-Attainment Regions

Non-attainment regions have more stringent regulatory requirements:

- New Source Review: permitting and review of any new major sources of criteria air pollutants, also mandatory offsets for new facilities after 1977.
- The Green Book has information on all current non-attainment regions and their status for each criteria pollutant.



Four Provisions of the Clean Air Act

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State Implementation Plans (SIPs)

State Implementation Plans (SIPs) vary across states. Some incorporate taxes, elements of cap-and-trade, and/or command-and-control approaches. Common elements:

- States determine which areas are in attainment, non-attainment, or unclassifiable for each criteria air pollutant.
- The state must then create a SIP outlining how the state will:
  - Bring all areas in non-attainment into attainment.
  - Ensure attainment areas remain so through permitting of new facilities.
  - Submit the SIP to EPA for approval, then EPA must agree.
- States may revise their SIP to designate new non-attainment areas or make adjustments to their plan after seeking public comment.

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New Source Performance Standards (NSPS)

New Source Performance Standards (NSPS):

- Organized around specific industries (“stationary sources”) or vehicles (“mobile sources”).
- Typically focus on criteria air pollutants.
- For each type of emitting facility, the regulator identifies an appropriate control technology and then sets an allowed emissions level based on that technology (i.e., hybrid technology/performance standard).
- NSPSs require monitoring to show compliance.
- Regulate ***new*** or ***modified*** existing sources of air pollution.
  - Incentive to keep dirtier facilities around (i.e., the Gruenspecht effect).

Examples of New Source Performance Standards (NSPS)

Some of the largest stationary sources:

- Steam Generating Power Plants
- Oil and Gas (includes fracking)
- Steel Plants
- Cement Plants
- Paper Mills
- Tire Manufacturing
- Oil refineries

Source: Westrock Paper Mill in Charleston (above), a cement plant (top-left), a fracking well (left).

Aside on Stationary Sources

New Source Performance Standards apply to “stationary” and “mobile” sources. *Stationary* is a regulatory and legal term that is not necessarily intuitive and that varies for each regulation.

- It could be a boiler with a smokestack.
- It could be the conveyer belt for a grain storage silo.
- It could also be multiple fracking wells in close proximity.
- It could even be distinct pumping stations along a gas pipeline, but not usually the entire pipeline.

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National Emission Standards for Hazardous Air Pollutants (NESHAPs)

Key facts on National Emission Standards for Hazardous Air Pollutants (NESHAPs):

- Control release of air toxics, aka “HAPs.”
- For each NESHAP, a positive regulatory determination requires EPA to make a list of all sources emitting the air toxic.
- EPA develops **Maximum Achievable Control Technologies (MACTs)** for each type of major source.
- NESHAPs include “area sources” subject to Generally Available Control Technologies (GACTs).
- NESHAPS do not require testing to confirm compliance, but they are legally enforceable.
  - ➢ Role for citizen science in ensuring compliance.

Examples of NESHAPS

Currently, there are 188 NESHAPS with specific regulatory requirements. Some NESHAPs cover topics you might recognize:

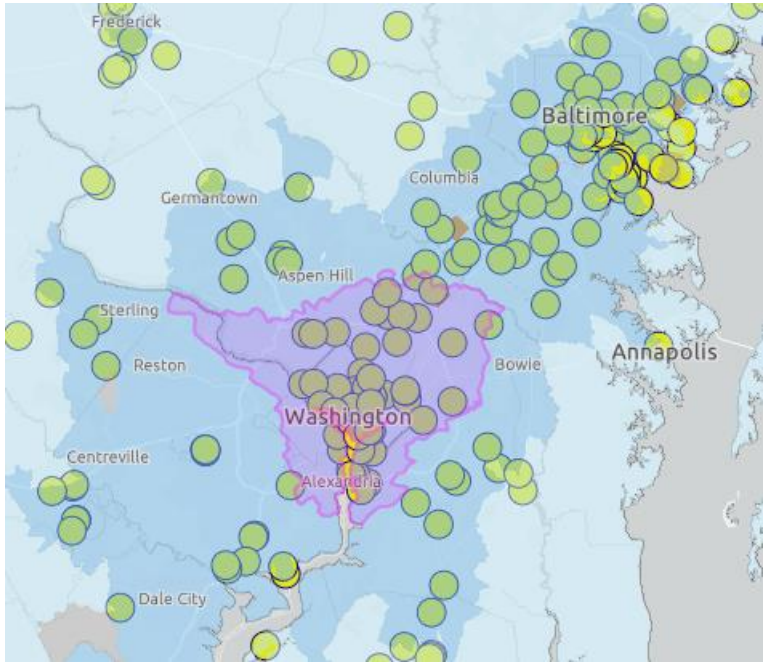
- Asbestos
- Dry-Cleaning Facilities (perchloroethylene)
- Wood furniture makers (formaldehyde, among other HAPs)

Others, not so much:

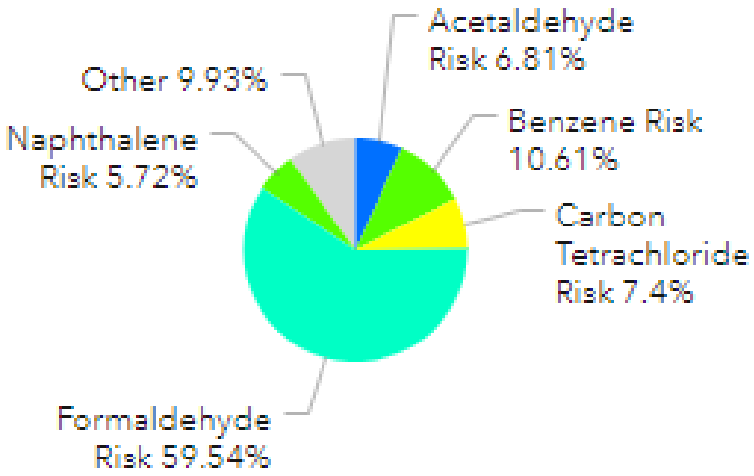
- Miscellaneous Organic Chemicals Manufacturing (i.e., “MON-MACT”)
- Hazardous Organic NESHAP: Synthetic Organic Chemical Manufacturing Industries (i.e., “HON-SOCMI”)

More on Air Toxics

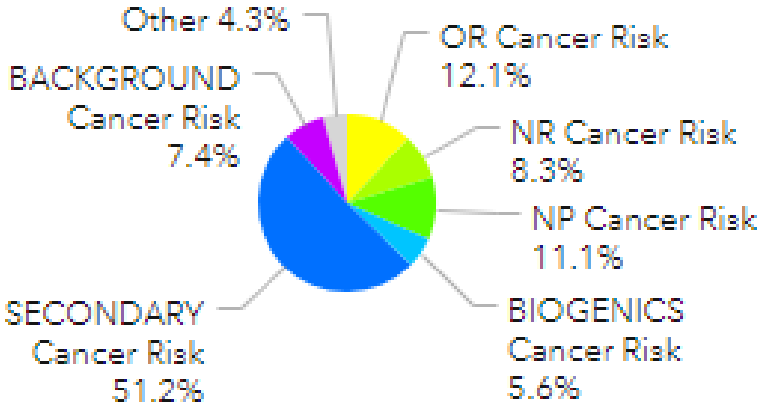
The AirToxScreen mapping tool* can be used to investigate local air toxics and emissions sources.



(a) Risk by Air Toxic



(a) Risk by Source Type



*AirToxScreen is only a screening tool, includes estimated concentrations, and does not capture all air pollutants.

Differences between NSPSs and NESHAPs

Differences between New Source Performance Standards and National Emissions Standards for HAPs:

- NSPSs start with a polluting industry or sector and determine the pollutants to be controlled; NESHAPs start with a HAP (or HAPs) and determine compliance controls for each industry that releases it.
- NSPSs employ “appropriate” controls; NESHAPs employ “maximum achievable control technologies.”
- NSPSs generally focus on criteria air pollutants; NESHAPs focus on more localized air toxics.
- NSPSs focus on new or modified sources; NESHAPs focus on new and existing sources.
- NSPSs require compliance testing; NESHAPs do not.

Part 2: Amending the Clean Air Act

Amending the CAA

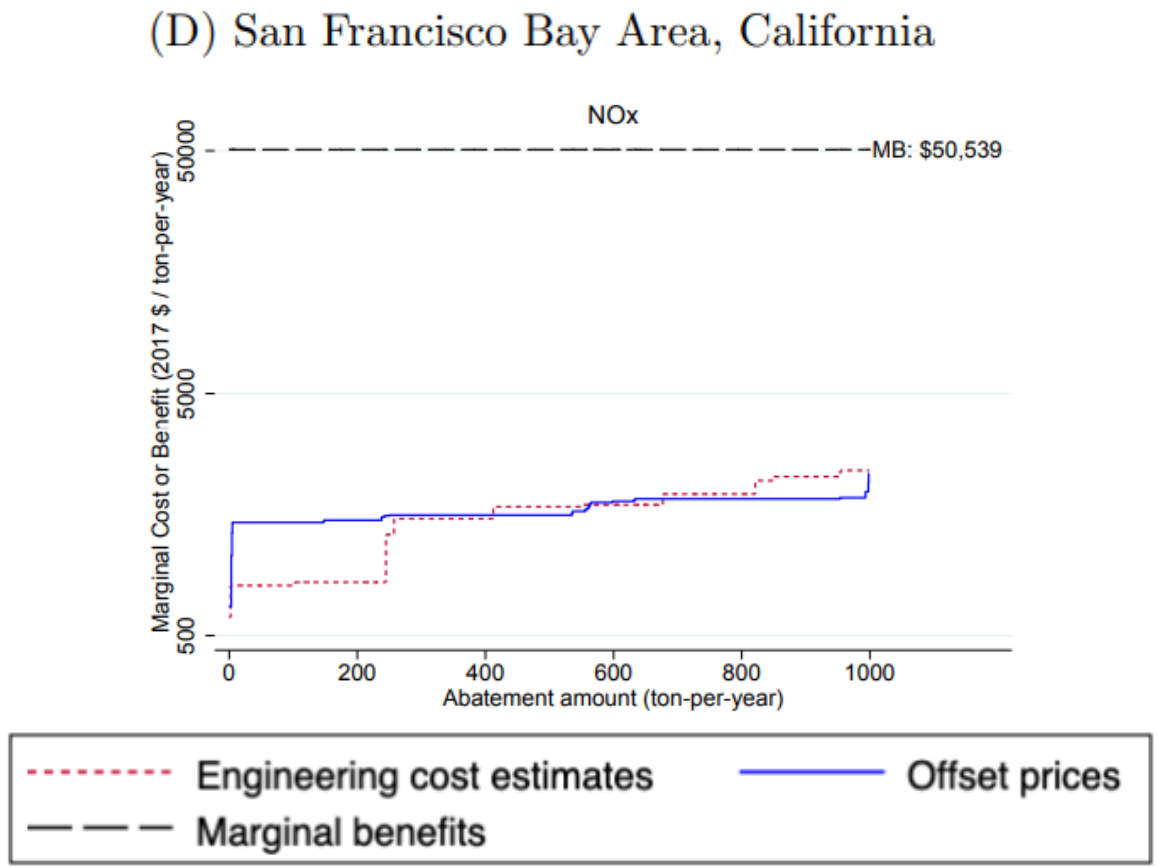
Early amendments to the Clean Air Act to increase stringency and improve cost effectiveness. Progress has largely stalled since 1990.

1) 1977 Clean Air Act Amendments
   - Required scrubbers on new power plants to remove sulfur dioxide.
   - Authorized emissions trading systems such as CA's RECLAIM.
   - Offsets markets for areas in non-attainment.
2) 1990 Clean Air Act Amendment
   - Emissions trading and taxes on the production and use of stratospheric ozone depleting substances.
   - Acid Rain Control Program created sulfur dioxide allowances and trading.

Offsets Markets

The original CAA did not allow new sources of emissions in areas that were out of attainment, but the 1977 amendments allowed them through "offsets."

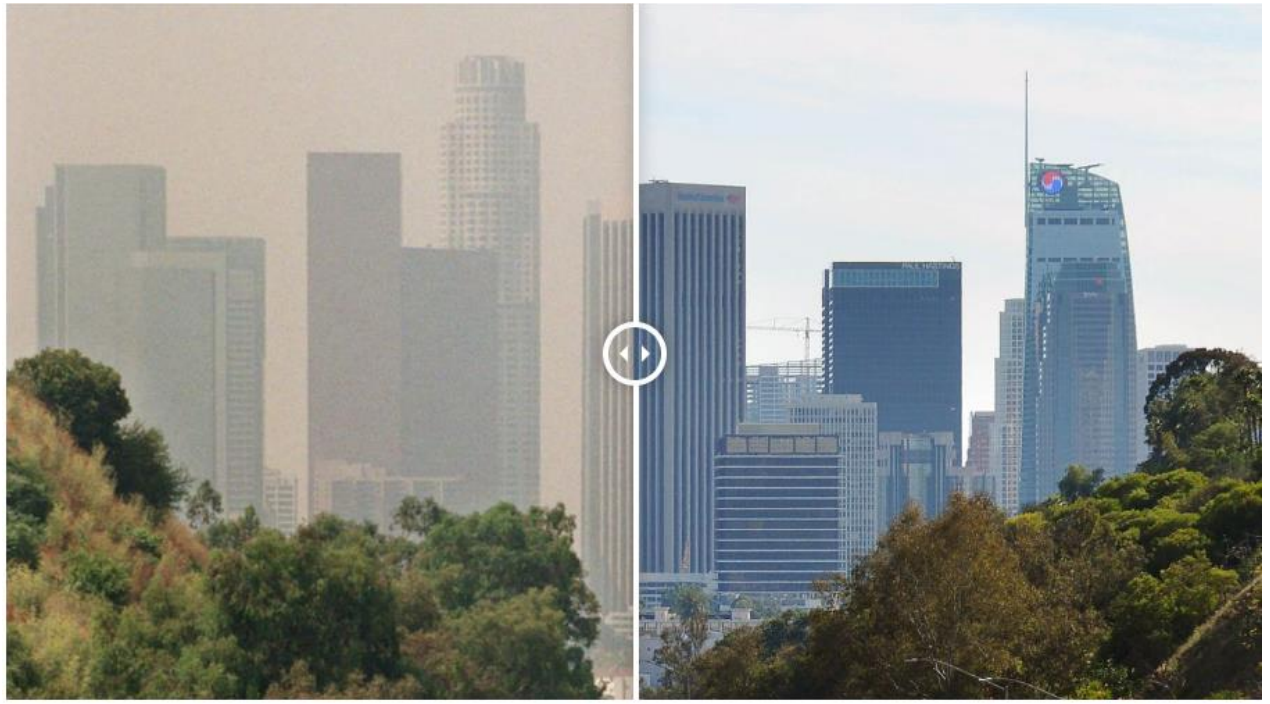
- A new source could be allowed if the increase in pollution emissions was offset by decreases of the same pollutants from sources in the nonattainment areas.
- Enabled the development of offset markets, where the price of an offset is a proxy for the marginal costs of abatement.
- Marginal benefits of abatement were roughly 10x higher than the price of an offset (Shapiro and Walker, 2020).



RECLAIM in California

In 1994, California introduced the REgional CLean Air Incentives Market (RECLAIM) as part of its SIP.

- 350 facilities emitting more than four tons of NO2 or SO2 had to meet certain emissions standards, but any surplus reductions would become RECLAIM Trading Credits (RTCs).
- New facilities had to purchase RTCs if they emitted these pollutants at sufficient quantities.
- Downwind sales of RTCs were prohibited.



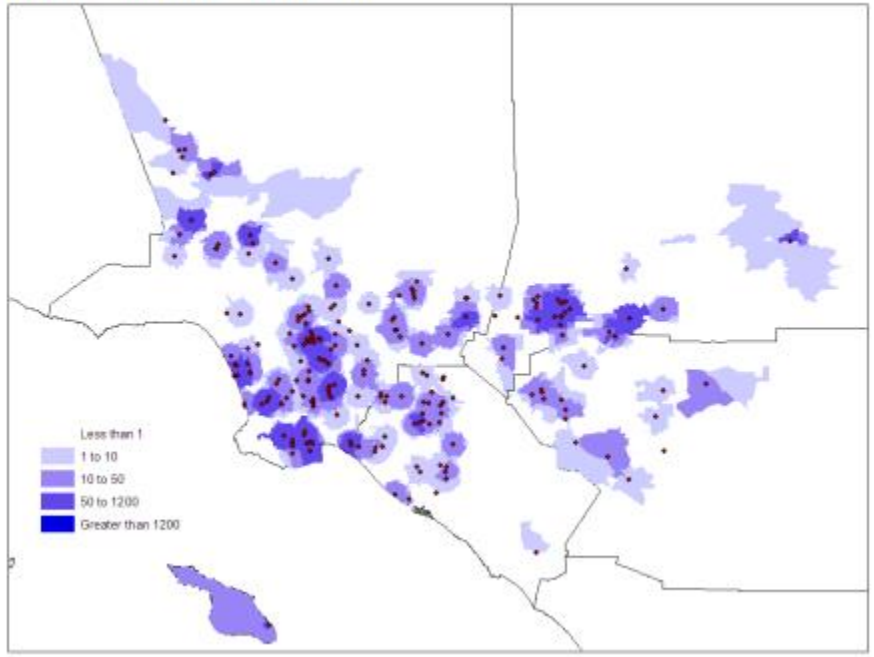
Source: *Los Angeles has notoriously polluted air. But right now it has some of the cleanest of any major city, CNN, 2020.*

RECLAIM in California

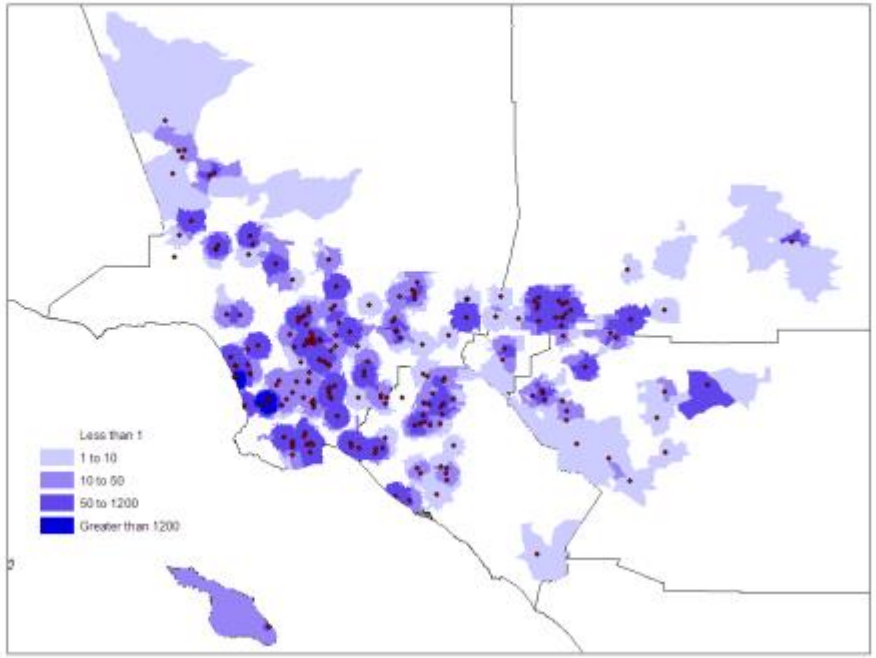
Literature on RECLAIM is somewhat mixed. There are positive reviews:

- Firms subject to the regulation reduced emissions by 20% compared to control facilities subject to command-and-control regulations and with large cost savings (Fowlie et al., 2012). Emissions of NO2 in the regulated area fell by 70% (Stavins, 2008).

Panel A: Actual Emissions under RECLAIM



Panel B: Counterfactual Emissions under Command-and-Control (CAC)



Actual Emissions under RECLAIM and Counterfactual, Command-and-Control Emissions in tons of Nitrogen Oxides. Source: Fowlie et al., 2011

RECLAIM in California

Others have criticized the program:

- Significant price volatility was politically costly. The regulated community was able to prevent additional lowering of the caps in the 2010s.
- The emissions reductions may have taken place regardless, abatement progress stalled after 2012, and some firms were not installing the newest abatement technologies (Wang et al, 2022).
- Ultimately, California decided to sunset their RECLAIM program, although they now have a GHG cap-and-trade program.

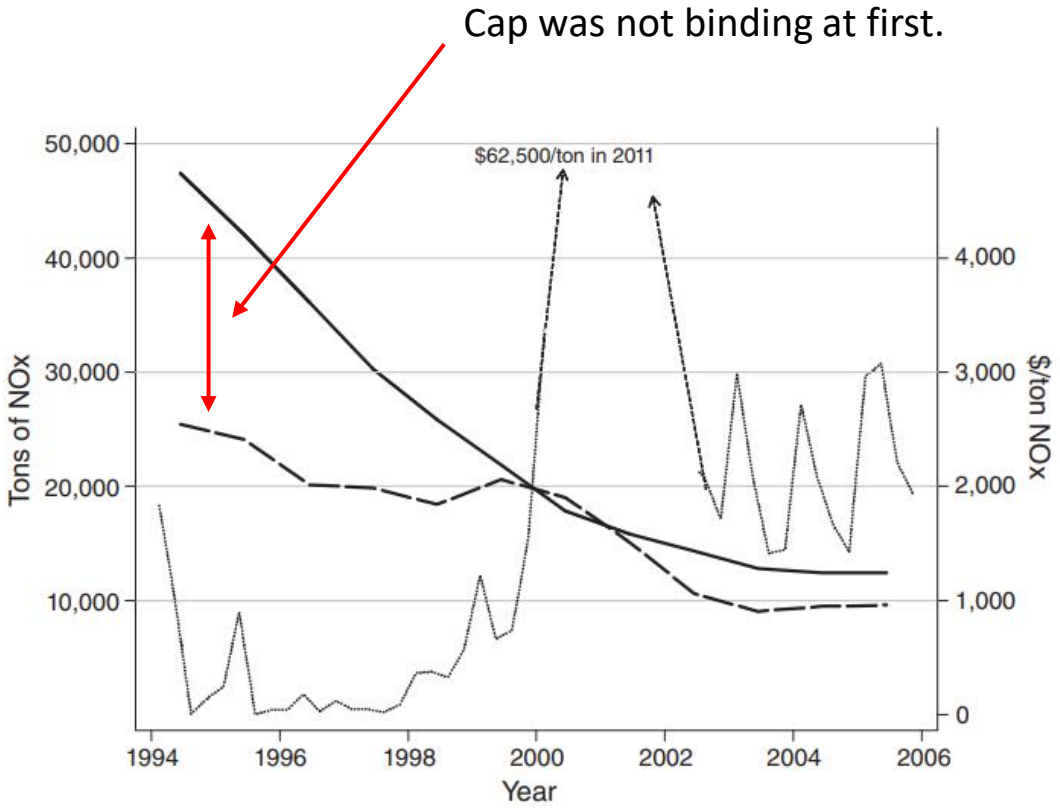


FIGURE 1

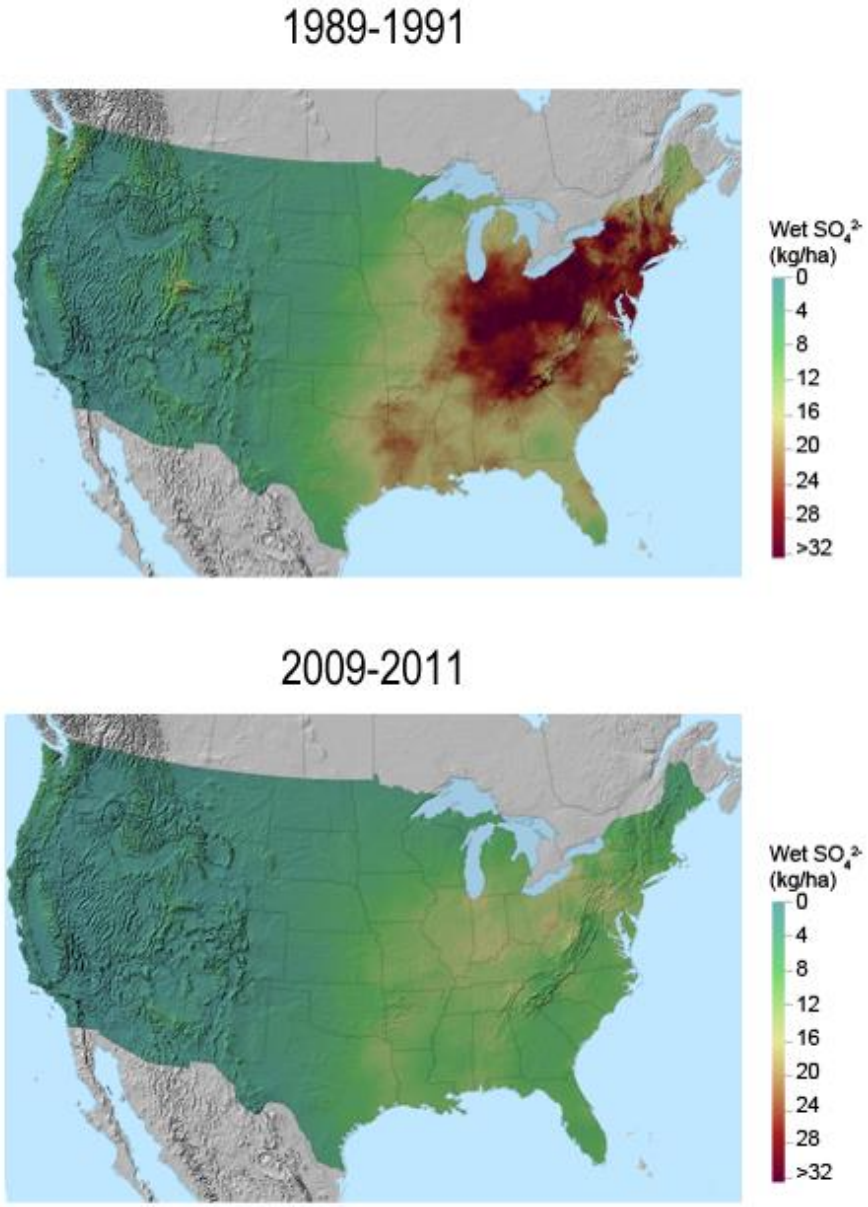
Note: Trends in nitrogen oxides emissions (dashed), allocations (solid), and permit price (dotted).

Source: Fowlie et al., 2012

Acid Rain Control Program

The Acid Rain Control Program was the first national cap-and-trade emissions program and also the first federal regulation of existing sources. Features:

- Cap of sulfur dioxide emissions below 50% of 1980 levels by 2010.
  - 36% reductions from 1990 to 2004, faster reductions than expected.
- Allowances handed out for free. EPA withheld 2.8% of all allowances for an auction, the proceeds of which went to new firms.
- Firms could “bank” allowances.

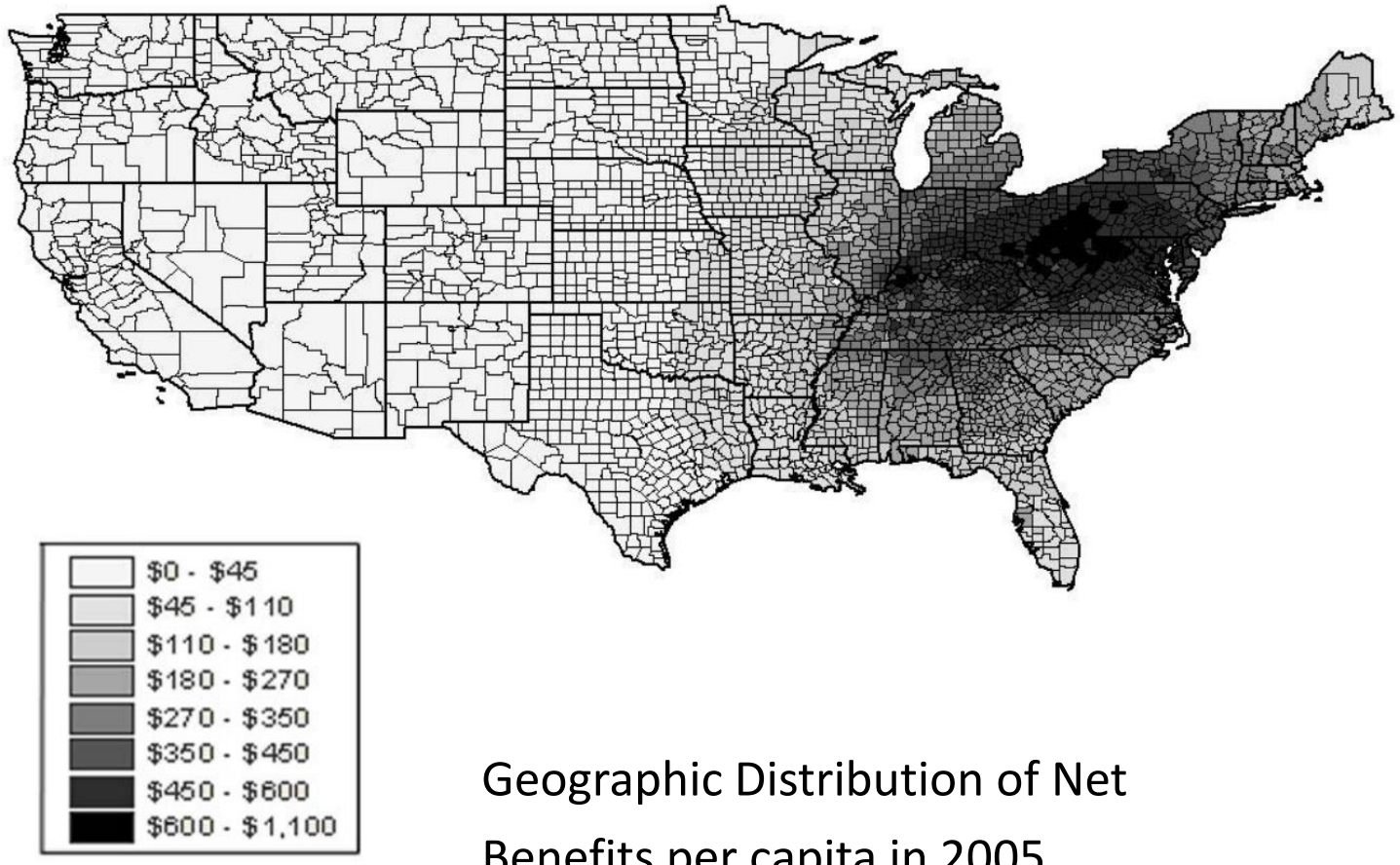


Wet Sulfur Deposition. Source: EPA, 2022.

Benefits of the Acid Rain Control Program

Overview of the benefits:

- Benefits were $56b and costs were only $556m (Shadbegian et al. 2005).
- 85% of the benefits were human-health based, not the ecological response that was the primary intent of the rule.
- Rule saw 2 million extra tons abated by mid 2000s.



Geographic Distribution of Net Benefits per capita in 2005

Cost Savings of the Acid Rain Control Program

Overview of the cost savings:

- Significant cost savings over a uniform emission fee or a technology standard.
- De-regulation of railroads made it cheaper to ship Wyoming low-sulfur coal as opposed to Appalachian high-sulfur coal, much cheaper than scrubbers.

Scenario	Estimated annual cost	Cost difference from Baseline	Cost Increase
Theoretical least-cost	$315m	-$432m	-57%
Baseline Cap and Trade	$747m	-	-
Uniform Emission Fee	$900m	$153	20%
Technology Standard	$2555m	$1808m	242%

Source: See your textbook, chapter 10.

More on Acid Rain Control Program

Reasons it worked well:

- Requirements were set in advance of the first compliance period, so there was less uncertainty and litigation.
- Transactions costs were reduced by removing requirements for approval by the regulator, leading to substantial trades (250,000 tons of trades at a price of $325/ton in 2008 alone)

Eventually, court decisions on the ability of EPA to modify the sulfur trading market and subsequent regulatory actions (Mercury Air Toxics Standard) eliminated the market.

Developments Since 1990

The period from 1990-2020 featured few new policy actions. Some developments:

- Greenhouse Gas Endangerment Finding (2009)
  - Allows regulation of six GHGs because they endanger public health and welfare, meaning that EPA has authority to regulate them under the CAA.
- 2009 Waxman-Markey Bill:
  - Failed greenhouse gas cap-and-trade bill.
- Obama-Era Regulations
  - NSPS for GHG emissions in the power sector that prevented new Coal-burning plants
  - Failed Clean Power Plan for existing sources, wide range of policy instruments
- Affordable Clean Energy Plan

Brief Recap

Table 1

Major Categories of Pollutants and Sectors Regulated by the Clean Air Act

	Policy instrument used			
	Technology standards	*Performance standards*	*Emissions trading*	*Taxes*
A: Pollutant categories				
Criteria pollutants	*	*	*	
Toxic/hazardous pollutants	*	*		
Stratospheric ozone depletion			*	*
Acid rain			*	
Greenhouse gases		Proposed	Proposed	
B: Regulated sectors				
Electricity generation	*	*	*	
Other stationary sources	*	*	*	*
Mobile sources	*	*		

Source: Schmalensee and Stavins (2019).

Outdated: Section 111(b) of the CAA for new gas electric generating units.

Part 3: Economics and the Clean Air Act

Economics and the CAA

The Clean Air Act requires a very multi-disciplinary support network. What role have economists played?

- More cost effective & efficient policy design.
- Insights on incentives and behavior of the regulators and the regulated.
- Monetizing unquantified endpoints.
- Causal inference to isolate new air pollution damage endpoints and improve accuracy of estimation for known damages.
- Disparate impacts of regulations and pollution changes (Sherriff, 2023; Hernandez-Cortes and Meng, 2023).

Monitoring Incentives under CAA

The CAA requires states to carry out self-monitoring of air quality standards for determining compliance → there are some perverse incentives.

- Strategic siting of air quality monitors (see Grainger and Schreiber, 2019 and similar prior work).
- Strategic shutoffs of air quality monitors when air quality is expected to deteriorate (see Mu, Rubin, and Zou, 2022).
  - ➢ Annual foregone health value of $67.4 million per interesting monitor.

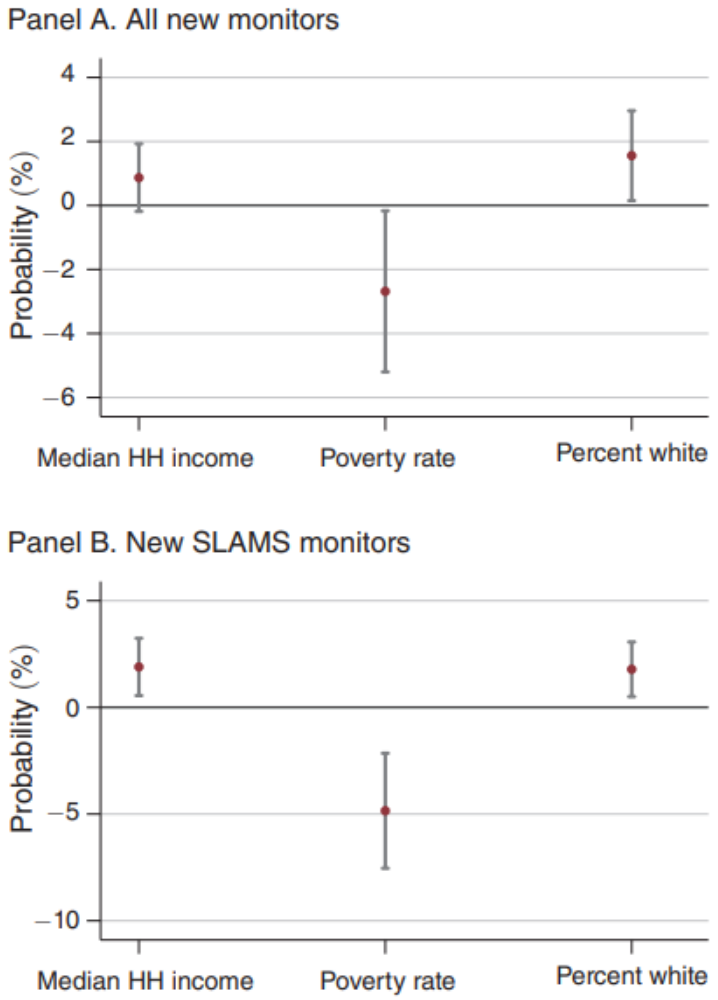
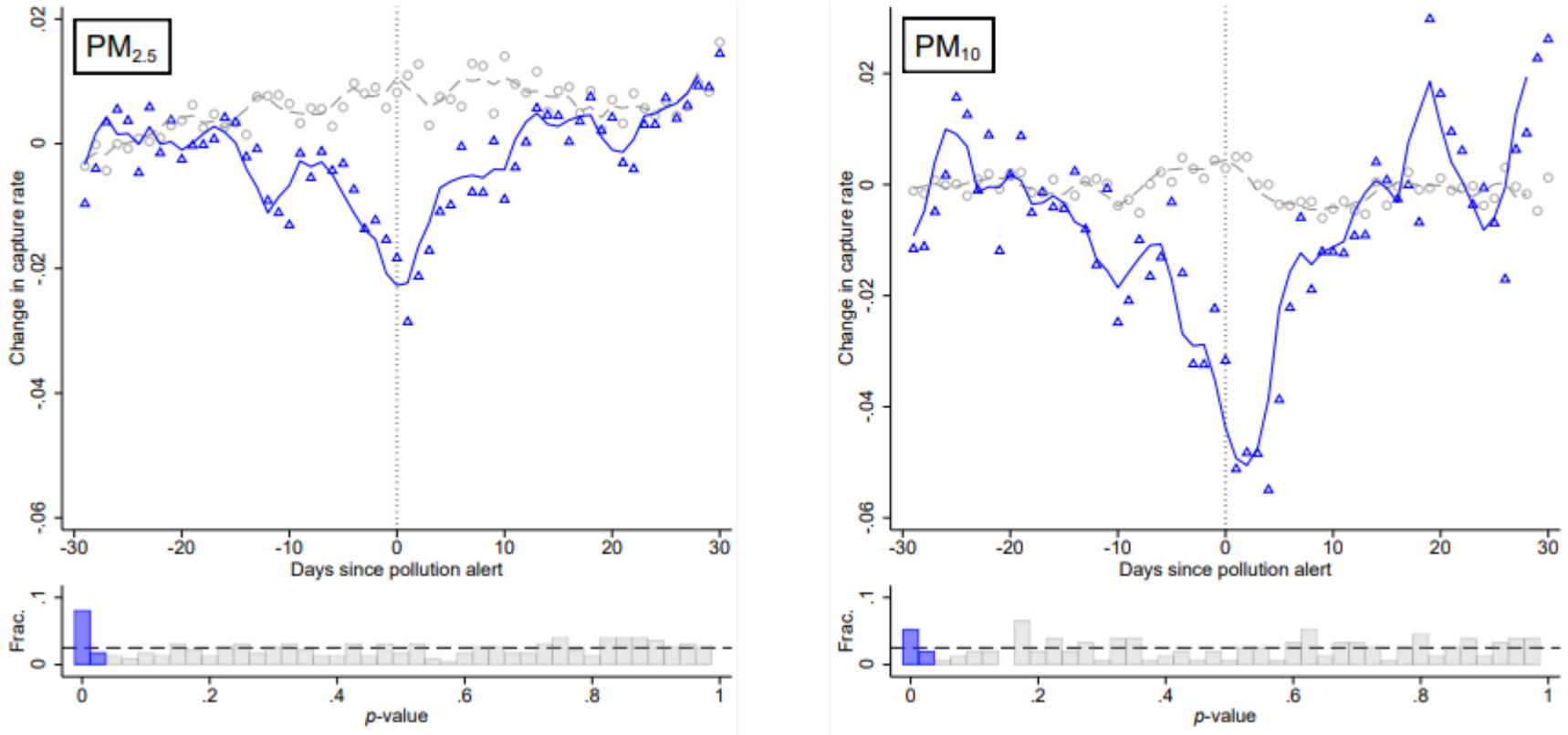


FIGURE 1. INTERACTION-TERM COEFFICIENTS

Mu, Rubin, and Zou (2022)

Figure 3. Capture Rate for "Interesting" Monitors (△) and Other Monitors (◯)



Check out this webmap to view all "interesting" monitors and download data from the study.

Chay and Greenstone (2005)

Authors use an instrumental variables approach based on non-attainment counties and total suspended particles (TSPs, or PM 10 + PM 2.5).

- Non-attainment counties reduce air pollution by more than control counties. Time-constant county characteristics are absorbed with county fixed effects.
- Hedonic price estimation of home values in non-attainment counties captures revealed preference of marginal willingness to pay for the change in TSPs.

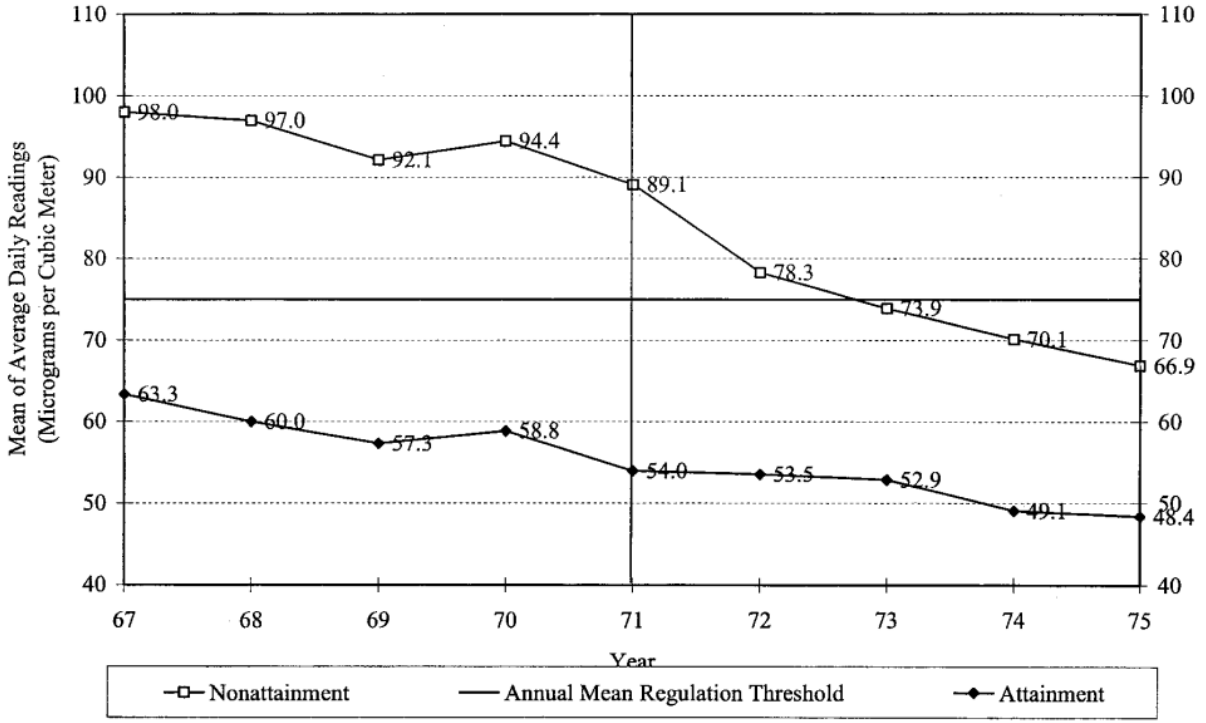


FIG. 2.—1967–75 trends in TSPs concentrations, by 1972 attainment status. The data points are derived from the 228 counties that were continuously monitored in this period. The 116 attainment counties had a 1970 population of approximately 25.8 million people, whereas about 63.4 million people lived in the 112 nonattainment counties in the same year. Each data point is the unweighted mean across all counties in the relevant regulatory category.

Chay and Greenstone (2005)

All counties reduced TSPs, but non-attainment by 22 vs. 6 for attainment counties.

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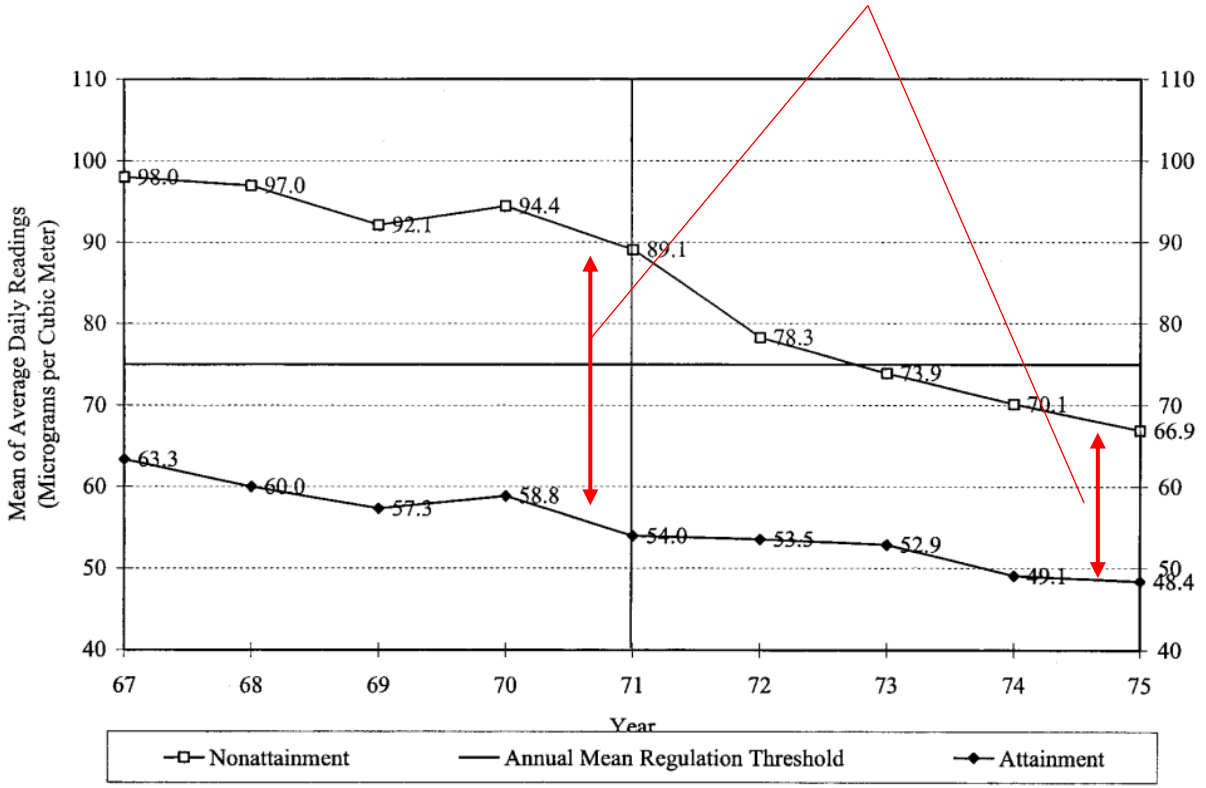

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Chay and Greenstone (2005)

Key findings:

- Counties in non-attainment reduced TSPs by 9-10 (ug/m3) because of the Clean Air Act's NAAQs requirements.
- Housing values in these regions increased by 2-3.6% after CAA non-attainment status designated. Roughly $5000 in today's dollars.
- Total benefits from 1970-1980 estimated to be $45 billion.

TABLE 4
ESTIMATES OF THE IMPACT OF MID-DECADE TSPS NONATTAINMENT ON 1970–80 CHANGES IN TSPS POLLUTION AND LOG HOUSING VALUES

	(1)	(2)	(3)	(4)
	A. Mean TSPs Changes			
TSPs nonattainment in 1975 or 1976	−9.96	−10.41	−9.57	−9.40
	(1.78)	(1.90)	(1.94)	(2.02)
F-statistic TSPs nonattainment*	31.3	29.9	24.4	21.5
	(1)	(1)	(1)	(1)
R^2	.04	.10	.19	.20
	B. Log Housing Changes			
TSPs nonattainment in 1975 or 1976	.036	.022	.026	.019
	(.012)	(.009)	(.008)	(.008)
F-statistic TSPs nonattainment*	8.5	6.2	9.3	6.4
	(1)	(1)	(1)	(1)
R^2	.01	.56	.66	.73
County Data Book covariates	no	yes	yes	yes
Flexible form of county covariates	no	no	yes	yes
Region fixed effects	no	no	no	yes
Sample size	988	983	983	983

NOTE.—See the notes to previous tables. In panel A the dependent variable is the difference between the 1977–80 and 1969–72 averages of mean TSPs concentrations. The mean is −7.82 $\mu g/m^3$. In panel B the dependent variable is the difference between 1980 and 1970 log housing values, and its mean is 0.27. Standard errors (in parentheses) are estimated using the Eicker-White formula to correct for heteroskedasticity.

Chay and Greenstone (2005)

Key findings:

- Counties in non-attainment reduced TSPs by 9-10 (ug/m3) because of the Clean Air Act's NAAQs requirements.
- Housing values in these regions increased by 2-3.6% after CAA non-attainment status designated. Roughly $5000 in today's dollars.
- Total benefits from nonattainment status 1970-1980 estimated to be $45 billion.

TABLE 4
ESTIMATES OF THE IMPACT OF MID-DECADE TSPS NONATTAINMENT ON 1970–80 CHANGES IN TSPS POLLUTION AND LOG HOUSING VALUES

	(1)	(2)	(3)	(4)
	A. Mean TSPs Changes			
TSPs nonattainment in 1975 or 1976	−9.96	−10.41	−9.57	−9.40
	(1.78)	(1.90)	(1.94)	(2.02)
F-statistic TSPs nonattainment*	31.3	29.9	24.4	21.5
	(1)	(1)	(1)	(1)
R^2	.04	.10	.19	.20
	B. Log Housing Changes			
TSPs nonattainment in 1975 or 1976	.036	.022	.026	.019
	(.012)	(.009)	(.008)	(.008)
F-statistic TSPs nonattainment*	8.5	6.2	9.3	6.4
	(1)	(1)	(1)	(1)
R^2	.01	.56	.66	.73
County Data Book covariates	no	yes	yes	yes
Flexible form of county covariates	no	no	yes	yes
Region fixed effects	no	no	no	yes
Sample size	988	983	983	983

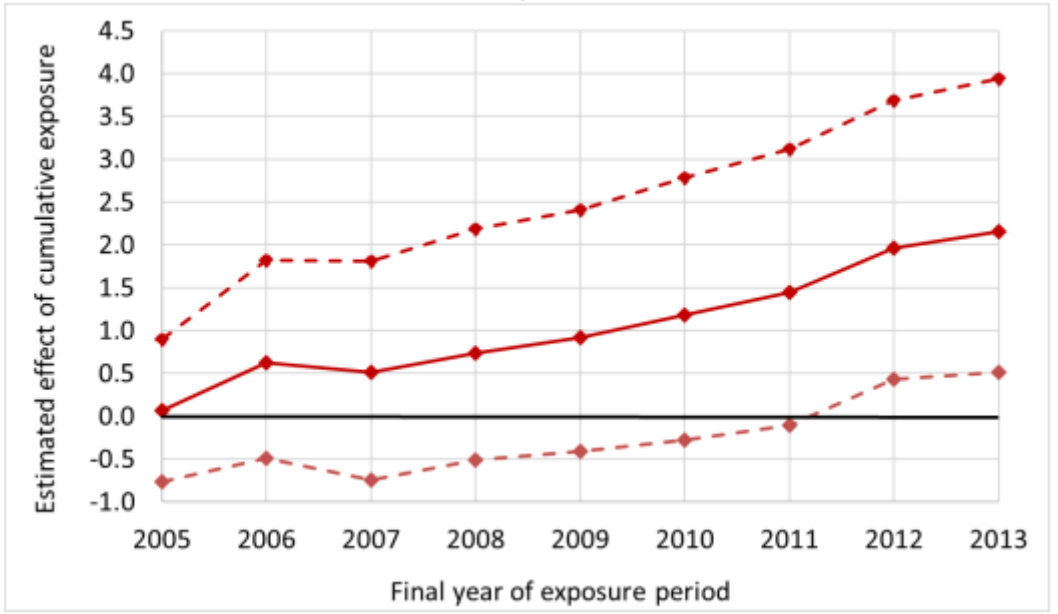
NOTE.—See the notes to previous tables. In panel A the dependent variable is the difference between the 1977–80 and 1969–72 averages of mean TSPs concentrations. The mean is −7.82 $\mu g/m^3$. In panel B the dependent variable is the difference between 1980 and 1970 log housing values, and its mean is 0.27. Standard errors (in parentheses) are estimated using the Eicker-White formula to correct for heteroskedasticity.

Clean Air and Cognitive Performance

Economics papers have demonstrated causal relationships between air pollution exposure and productivity, cognitive performance, and dementia.

- Worse air pollution lowers fruit harvesting speeds (Neidel, 2017).
- Lowers performance on the Bagrut, an SAT-like exam in Israel (Lavy et al., 2014).
- Lowers performance on Lumosity tests (Krebs and Luechinger, 2023).
- Increases risk of dementia by 2.2 PP or 11% from mean (Bishop et al., 2022)

FIGURE V: ESTIMATED EFFECTS OF $PM_{2.5}$ ON DEMENTIA BY EXPOSURE DURATION



Hernandez-Cortes, Meng, and Weber (2022)

Research question: How has exposure to air pollution from the fossil fuel electricity sector changed over time and for whom?

Methods:

- Continuous Emissions Monitoring Systems (CEMS) information on all electricity-generating units producing over 25 MW.
- Energy Information Administration (EIA) Form 860 on plant characteristics.
- InMAP emissions pollution transport model.
- For each location (and community), calculate population-weighted pollution exposures attributable to each type of facility and type of fuel.

Hernandez-Cortes, Meng, and Weber (2022)

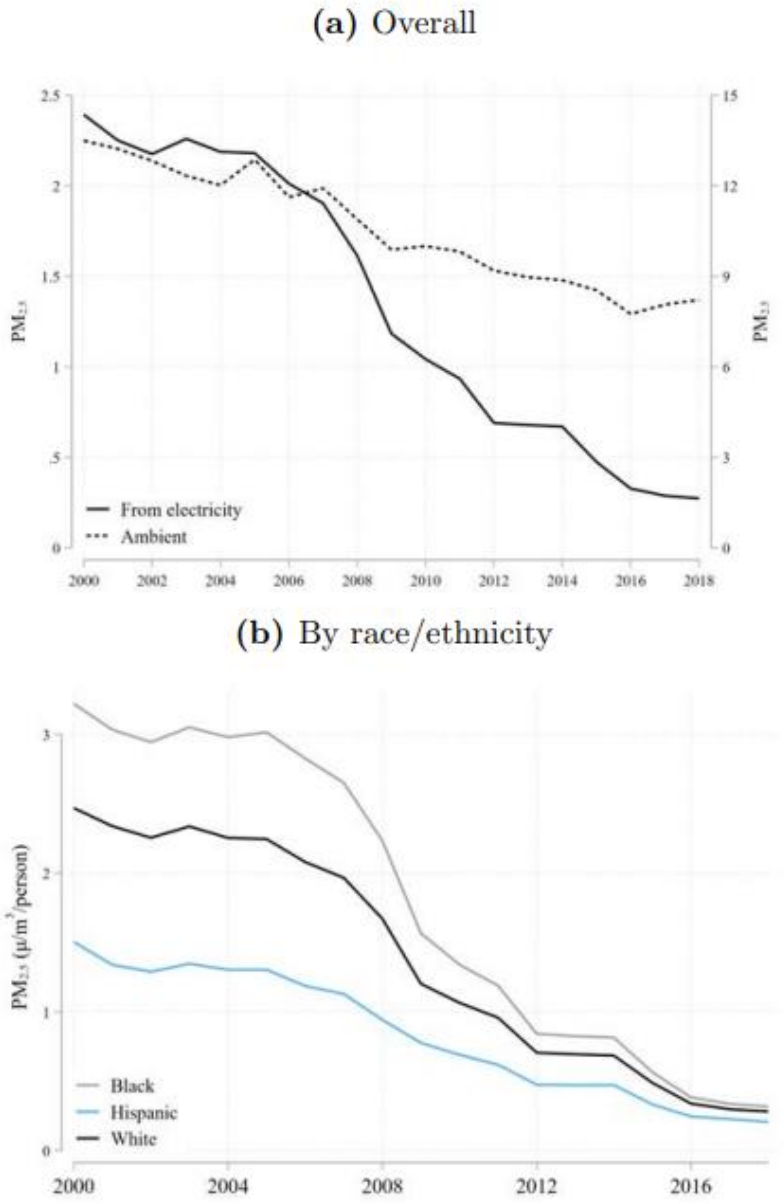
Four primary findings:

1) Air pollution exposures due to fossil fuel electricity generation have dramatically decreased from 2000-2018, by 89% for the average individual.

2) Decrease is largely shared across demographic groups, falling by 90%, 86%, and 89% for the average Black, Hispanic, and non-Hispanic White individual.

- This implies a decrease in absolute disparities of exposure (Black-White disparity decrease of 0.75 → 0.036 ug/m3, or 95%).

Figure 4: Trends in pollution concentrations by demographics



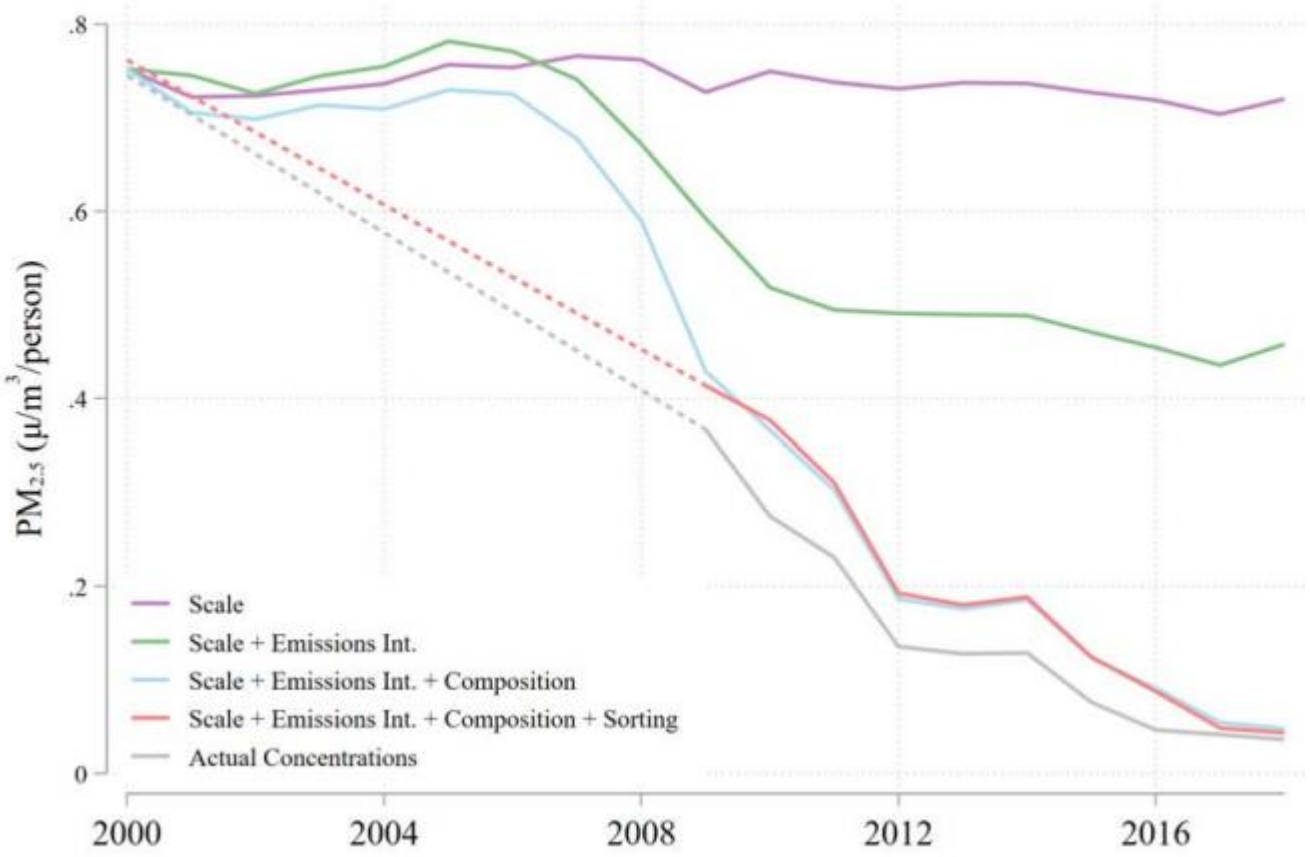
Hernandez-Cortes, Meng, and Weber (2022)

Four primary findings:

3) Trends in disparities are equally attributable to lowered emissions at a given unit and changes in the types of generating units, not migration.

Figure 6: Decomposition of pollution disparity trends

(a) Black-White disparity

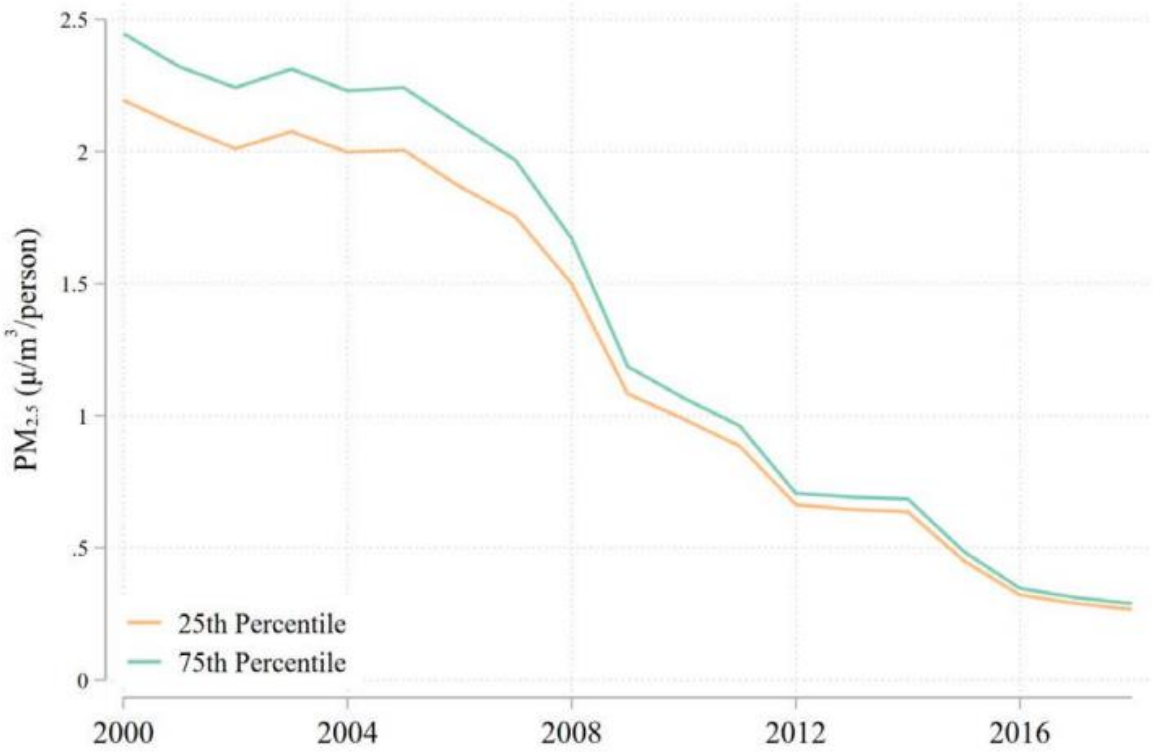


Hernandez-Cortes, Meng, and Weber (2022)

Last of the four findings:

4) Exposure disparities by income were always small, and mostly decreased proportionally.

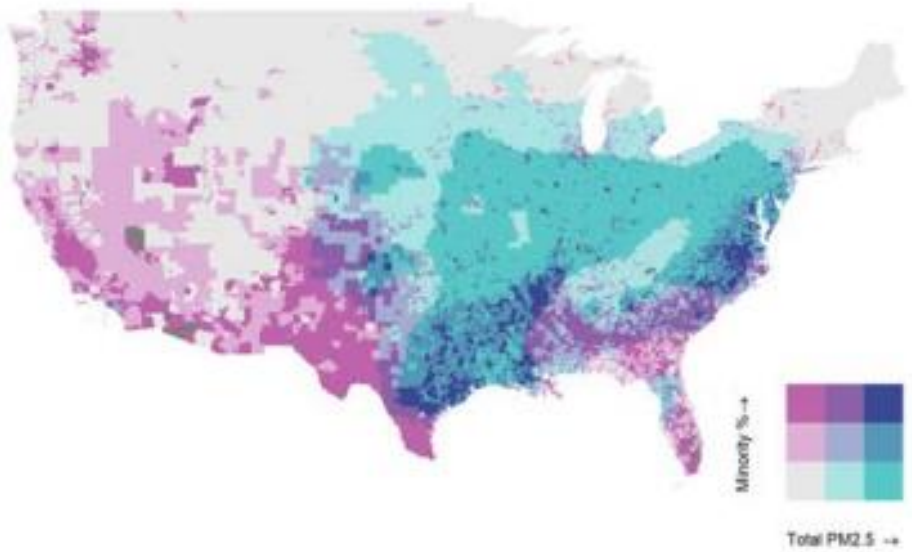
Figure A5: Trends in pollution concentrations by income quartiles



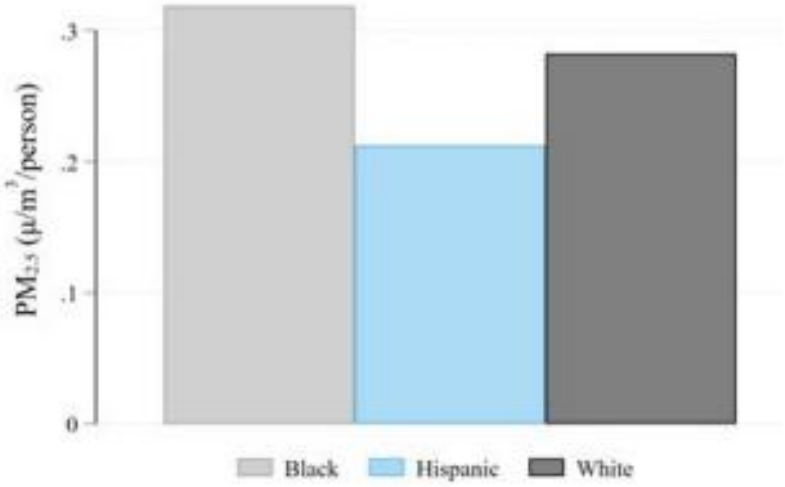
Hernandez-Cortes, Meng, and Weber (2022)

Figure 3: $PM_{2.5}$ concentrations by demographic groups

(a) Distribution of $PM_{2.5}$ and minority share



(b) $PM_{2.5}$ by race/ethnicity



Next class

- Next class will cover environmental regulations of cars.

- For Wednesday, please read/listen to:
  - Killeen and Levinson (2017)
  - Transportation Justice Podcast