

The geography of environmental regulation: Welfare and distributional impacts of the CAA

Alex Hollingsworth

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TREE Seminar

Environmental regulation improves amenities



South Boston, MA in 1973 and 2012

Environmental regulation raises costs

Clean Air Act compliance will be costly, official says

By MAGGIE SIEGER
The Daily News

Galveston County must reduce toxic emissions by at least 15 percent no later than Nov. 1, 1996, or face losing massive amounts of federal dollars, said Texas Water Commissioner Pam Reed.

Reed met Tuesday with the Island Rotary Club to discuss the Clean Air Act amendments, federal laws that require cities to clean up air and water quality or lose federal funding. The amendments, passed in 1990, apply to a variety of small businesses never before subjected to regulation, Reed said.

The Texas Water Commission will assume the responsibilities of the Texas Air Control Board Sept. 1, becoming the Texas Natural Resource Conservation Commission. The

A three-member water commission board will oversee the new commission.

Texas must have a plan on how it will reach federally mandated clean air standards by 1994, Reed said.

The Houston-Galveston area, composed of eight counties, is the only area in the state classified as severely out of compliance. The classification allows the region until 2007 to reach some federal standards. El Paso, Dallas-Fort Worth and Beaumont are the only other Texas regions classified as out of compliance.

The cost of reaching compliance will be extremely high, Reed said. She had no spe-

ENVIRONMENT

See AIR, 11-A

Business

The Indiana, PA Gazette Sunday, April 25, 1993

Stock market continues slide Page D-2
There's a workshop on state taxes Page D-2
Gazette classified ads Pages D-6, 7, 8

Penelec pegs \$210 million to help clear air

\$135.5 million at Conemaugh Station

Spending for environmental improvements at generating stations owned or operated by PennTec — including scrubbers at Conemaugh Station — is expected to top \$10 million this year, or double what was spent last year and 18 times what was spent in 1987.

The increases are due primarily to improvements needed to comply with the Clean Air Act amendments of 1990, the company said.

The company plans to spend \$88.3 million at stations it owns, with the remaining \$171 million coming from utilities which own all or parts of other stations operated by Penobscot.

Will be spent on installation of a desulfurization system — known as scrubbers — at the Conemaugh Station in Indi-

scrubber work at Unit 3 and that project should be completed by late 1990, Slownik said. "Although the scrubbers are a big-ticket project, they aren't the only work we have to do to comply with the Clean Air Act amendment," Slownik said. "This year, we will also be studying the possibility of installing scrubbers at another station and will be spending more than \$35 million to install special low-NO_x burners at boilers in a number of stations."

WPS is responding to the Clean Air Act amendment needs.

A 5-mile radius determines the feasibility of

Installing scrubbers at Homer City Station Unit 5, which is a \$1.8-million study.

- Installation of low-NO_x burners to reduce nitrogen oxide emissions at Conemaugh Station, \$1.5 million; Homer City Station, \$1.5 million; Seward Station, \$1.5 million; Shawville Station in Clearfield County, \$1.5 million; Keyser Station in Armstrong County, \$1.1 million; and Warren Station in Warren County, \$125,000.

These outlays will be supplemented by money to be spent in 1994 and 1995 to complete most of these projects, it was said.

Low-NO_x burners are expected to reduce

emissions at the respective generating units by approximately 90 percent.

- A study regarding installation of large filters that will remove 99.9 percent of the fly ash from the flue gas leaving the plant's stacks, \$2.3 million.
- Coal-reuse site development, \$1.8 million

• Fly-ash disposal site development and
use.

• Upgrades to a wastewater-treatment facility will be made to accommodate

facility will be made to accommodate increased waste water produced by the station's scrubbers, \$1.6 million. Again, Slowik added that spending more money on those ongoing projects is anticipated in the

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What is the incidence of costs and benefits across space and sectors?

What role did physical and economic geography play in the aggregate and distributional effects?

→ Migration, trade, pollution transport, GE effects

NAAQS in spatial general equilibrium

- 1 We develop an integrated spatial assessment model
 - Eaton and Kortum (2002) Ricardian model
 - Inter-county and inter-industry reallocation
 - Muller and Mendelsohn (2009) AP3
 - Emissions and damages endogenously move along with reallocation
 - Focus on (secondary) PM_{2.5} damages

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- 2 We structurally estimate impacts on emissions and productivity
- 3 We simulate the spatial equilibrium effects of nonattainment designations in 1997
 - First geographic/equilibrium analysis of the CAA: use novel trade cost data (Jaworski and Kitchens, 2021)

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- Labor reallocation has small aggregate **negative** effects
 - Lots of heterogeneity: -2% to +0.5% effects

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Economic geography: reduced form evidence shows firms and workers reallocate across space and sectors in response to nonattainment
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Physical geography: emissions cross county borders and alters amenities in other locations

- Reallocation of emissions affects amenities and sorting **everywhere**

Roadmap

Step 1: Institutional background

- What are the NAAQS and how do they work?

Step 2: Estimation + Quantitative Model

- EK model linked to AP3
- Estimate impacts on implicit marginal cost of emissions
- Estimate impacts on firm fundamental productivity

Step 3: Results

- What if nonattainment counties in 1997 never went into nonattainment?

What are the NAAQS?

Pollutant [links to historical tables of NAAQS reviews]	Primary/ Secondary	Averaging Time	Level	Form
Carbon Monoxide (CO)	primary	8 hours	9 ppm	Not to be exceeded more than once per year
		1 hour	35 ppm	
Lead (Pb)	primary and secondary	Rolling 3 month average	0.15 µg/m ³ (1)	Not to be exceeded
Nitrogen Dioxide (NO ₂)	primary	1 hour	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
	primary and secondary	1 year	53 ppb (2)	Annual Mean
Ozone (O ₃)	primary and secondary	8 hours	0.070 ppm (3)	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years
Particle Pollution (PM)	PM _{2.5}	primary	1 year	12.0 µg/m ³ annual mean, averaged over 3 years
		secondary	1 year	15.0 µg/m ³ annual mean, averaged over 3 years
	primary and secondary	24 hours	35 µg/m ³	98th percentile, averaged over 3 years
	PM ₁₀	primary and secondary	24 hours	150 µg/m ³ Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide (SO ₂)	primary	1 hour	75 ppb (4)	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
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Counties violating the standard are designated as in nonattainment

Enforcement of nonattainment

Counties in nonattainment are subject to:

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- Potential federal sanctions, fines, or loss of federal funding if SIP isn't followed or developed

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- Lower productivity, capital, and output (Greenstone, 2002; Greenstone, List and Syverson, 2012)
- Fewer plant openings and increased plant and worker exit (Henderson, 1996; Becker and Henderson, 2000; Walker, 2013)

Increases costs in polluting industries

Who Pays for the Clean Air Act?

By Susan Lee

This time around, Washington couldn't be prouder. Twenty years ago, when the major provisions of the Clean Air Act were adopted, the word "cost" was hardly mentioned. Now, with the bill in a House-Senate conference, the debate over amendments to the act is filled with figures purporting to capture the cost of the tiniest provision.

The trouble is, it's all hot air. Nobody has any idea what it will cost — we're talking about a conspiracy of silence on who will pay the bill.

There are plenty of estimates of the total cost. Unfortunately, the range is large: respectable guesses run from \$22 billion to more than \$100 billion a year, and almost nobody is willing to declare any number definitive.

As laughably flabby as the cost estimates are, at least they define the territory. Getting a grasp on the dollar number for benefits is like charting Planet Debbie: virtually impossible. The problem is that the benefits from cleaner air are broad. They include everything from fewer deaths from lung cancer to more relief from sinus headaches.

Thus, estimating the money saved has to take into account profound speculation — like the value of a life (perhaps \$2 million to \$10 million), savings in medical treatments and days lost due to respiratory diseases. It should include, too, less profound categories such as less frequent house painting and reduced damage to national monuments. Tossing this up is a mug's game; unsurprisingly,

there are no reliable estimates of the benefits.

Why, then, do we seem so eager to pass legislation that could be as expensive as \$100 billion a year without knowing whether the benefits will justify the cost? Simply put, the discussion is not focused on who, ultimately, will pay. Instead, there is an implicit promise that the Clean Air Act will be a free lunch.

Ask who will pay the bill, and the answer is that business will have to ante up. Granted, the added cost will be felt first by the tens of thousands of businesses that must comply with



new regulations on acid rain, toxic emissions and urban smog.

Utilities will have to cut back on cheaper high-sulfur coal and use more expensive low-sulfur coal or install scrubbers to reduce sulfur dioxide emissions. Auto companies will have to reduce emissions of hydrocarbons and nitrogen oxide, and small businesses like bakeries, gas stations and restaurants will have to control their use of alcohol- and petroleum-based products to contribute to smog. Chemical and steel companies — and dry cleaners, auto body shops and paint control companies — will have to buy new equipment to control airborne toxic substances. □

Susan Lee is writing a book on the origins of economic crises.

But in the final analysis, business doesn't pay. We pay. Business will pass the increased cost along. Either consumers will pay in the form of higher prices for products or services, or workers will pay in the form of lower wages, or shareholders will pay in the form of lower dividends or stock prices.

That means we all will pay more for electricity, gasoline, cars, bread and paint. Workers in affected industries, like steel and mining, will absorb the cost by receiving lower pay hikes or benefits. People who own stock in utility or oil companies will find their dividends are lower or their stocks are worth less. And owners of mom-and-pop dry cleaners will take out less profit.

There is an indirect cost to all of us, too, because the economy won't grow as fast as it could otherwise. After all, money spent for pollution control cannot be spent to make widgets. Likewise, it cannot be spent for new equipment to produce widgets more efficiently.

Finally, the added cost to business will diminish the attractiveness of doing business here, and companies will relocate to other countries, taking production and jobs with them.

Perhaps the blank-check aspect of the Clean Air Act cannot be avoided. The law will mandate what experts agree are sensible goals, and incorporate efficient ways of achieving those goals. But as the House goes to Congress, the Administration and environmentalists should come clean and point out who will ultimately cough up the money. Twenty-two billion dollars to \$100 billion would buy a lot of research on breast cancer, Alzheimer's and heart disease. That's a significant trade-off — one that ought to be considered since the direct cost could be \$90 to \$450 a person a year. □

E.P.A. ADVOCATING HIGHER STANDARDS TO CLEAN THE AIR

INDUSTRY WARNS OF COSTS

In Areas Struggling to Reduce Pollution, New U.S. Goals Could Be Hard to Meet

By JOHN H. CUSHMAN Jr.

WASHINGTON, Nov. 24 — The Environmental Protection Agency is recommending tighter national standards for emissions of the chemicals and particles that form smog and soot, some of the most pervasive and unhealthy forms of air pollution.

The new definition of how clean the air must be to protect the public's health is sure to be one of the biggest environmental fights of the coming year, ranging from the Oval Office to Capitol Hill and drawing in Federal judges and governors.

Polluting industries shut down or move

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Benefits persist in subsequent (not exposed!) generations (Colmer and Voorheis, 2020)

Reduces emissions locally and elsewhere

Countless Costs to New York From Clean Air Act

By ALLAN R. GOLD

For residents of the metropolitan region, the cleaner air will carry a price that will exceed all but a few other parts of the country, reflecting the intensity of the air pollution problem.

When the new Clean Air Actions are phased in several years from now, consumers will probably pay more for gasoline, electric cleaning, paint, bagels and even restaurant meals. Much of the cost will absorb some of those increases, but only the most places face such an array of rises.

None of this will happen immediately.

"The road is long to clean air," said Nancy Seidman, acting executive director of Northeastern States Coordinated Air Use Management, a region-based coalition of state air departments. "Most of these changes won't take effect until the mid-1990s."

Neckties, Bagels, Even Motor Vehicles

In fact, New York will be allowed an additional 17 years from the time the law is enacted to reach Federal clean air standards. The city has never done so in the 20 years of the Clean Air Act.

"For children who are born in New York City now, the law could be providing clean air by the time they graduate from high school," said Eric A. Goldstein, a senior lawyer at the Natural

Resources Defense Council in New York, a nonprofit environmental group.

Dry cleaning and

New York State is permitted under the Clean Air Act to adopt California's rules, and it fought hard to stay in the new law. California has the worst air pollution, recently decided to bigger reductions in tailpipe emissions.

On Sept. 1, New York State's Conservation Commission said yesterday that the state would follow California in those rules starting in 1998.

Corridor of Smog

Some 40 percent of the metropolitan region's smog is contributed by sources as far south as Washington, Mr. Jorling said. To address this problem in a 13-state Northeast region, the new clean air law requires controls on many additional industrial sources of smog. Also, motor vehicle inspection

paints and other coatings, solvents and aerosols like deodorants.

Some of the biggest costs will be for changes in transportation and energy required by the law.

By 1995, gasoline may cost a few cents more a gallon as a result of the rules, because refiners will be required to alter both production and the gasoline itself to control toxic, smog-form-

ing Philadelphia, San Diego, Milwaukee, Baltimore and Hartford.

Congress also agreed to tighten tailpipe emissions standards beginning in 1994, but last month New York State took steps to require similar controls in 1993. Regulators say the tighter standards could add \$150 to the cost of a car; the auto industry has asserted it will cost more.

ing power. New York utilities routinely purchase power from generators in other states, like Pennsylvania, which may have to spend millions of dollars to reduce sulfur dioxide emissions.

"To the extent that New York buys from other grids, the price may reflect that," Ms. Seidman said. Grids are integrated networks over which utilities trade electricity and bill each other.

Model: Firm production

$$q_i^k = \left[\prod_{p=1}^P (e_i^{kp})^{\xi^{kp}} \right] [z_i^k (K_i^k)^{1-\gamma} (L_i^k)^\gamma]^{1-\sum_{p=1}^P \xi^{kp}}$$

Perfectly competitive firms in location i and industry k produce different varieties ω using a CRS Cobb-Douglas technology combining:

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γ is the aggregate labor share from FRED

Model: Emissions

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Inverting CD factor shares gives us equilibrium emissions intensity:

$$\frac{e_i^{kp}}{q_i^k} = \frac{\xi^{kp} P_i^k}{\eta_i^{kp}}$$

The effect on the MC of emissions

We let $\eta_i^{kp} = \bar{\eta}_i^{kp} \exp(\beta_\eta^p N_i)$ where $N_i \in \{0, 1\}$ is an indicator for being in nonattainment

→ $\bar{\eta}_i^{kp}$ captures the impact of other regulations

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→ $\bar{\eta}_i^{kp}$ captures the impact of other regulations

Equilibrium emissions are given by:

$$\underbrace{\log(e_i^{kp})}_{\text{emissions}} = \underbrace{-\beta_\eta^p N_i}_{\text{nonattainment}} + \underbrace{\log(w_i^k L_i^k)}_{\text{wage bill}} + \underbrace{\log\left(\frac{\xi^{kp}}{\gamma(1 - \sum_{q=1}^P \xi^{kq})}\right)}_{\text{emissions share / labor share}} - \underbrace{\log(\bar{\eta}_i^{kp})}_{\text{emissions price}}$$

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Emissions decline in: non-attainment, price of other regulations

The effect on the MC of emissions

$$\underbrace{\log(e_i^{kp})}_{\text{emissions}} = \underbrace{-\beta_\eta^p N_i}_{\text{nonattainment}} + \underbrace{\log(w_i^k L_i^k)}_{\text{wage bill}} + \underbrace{\log\left(\frac{\xi^{kp}}{\gamma(1 - \sum_{q=1}^P \xi^{kq})}\right)}_{\text{emissions share / labor share}} - \underbrace{\log(\bar{\eta}_i^{kp})}_{\text{emissions price}}$$

Emissions decline in: non-attainment, price of other regulations

Emissions increase in: production, share of emissions in production

1990 CAAAs quasi-experiment

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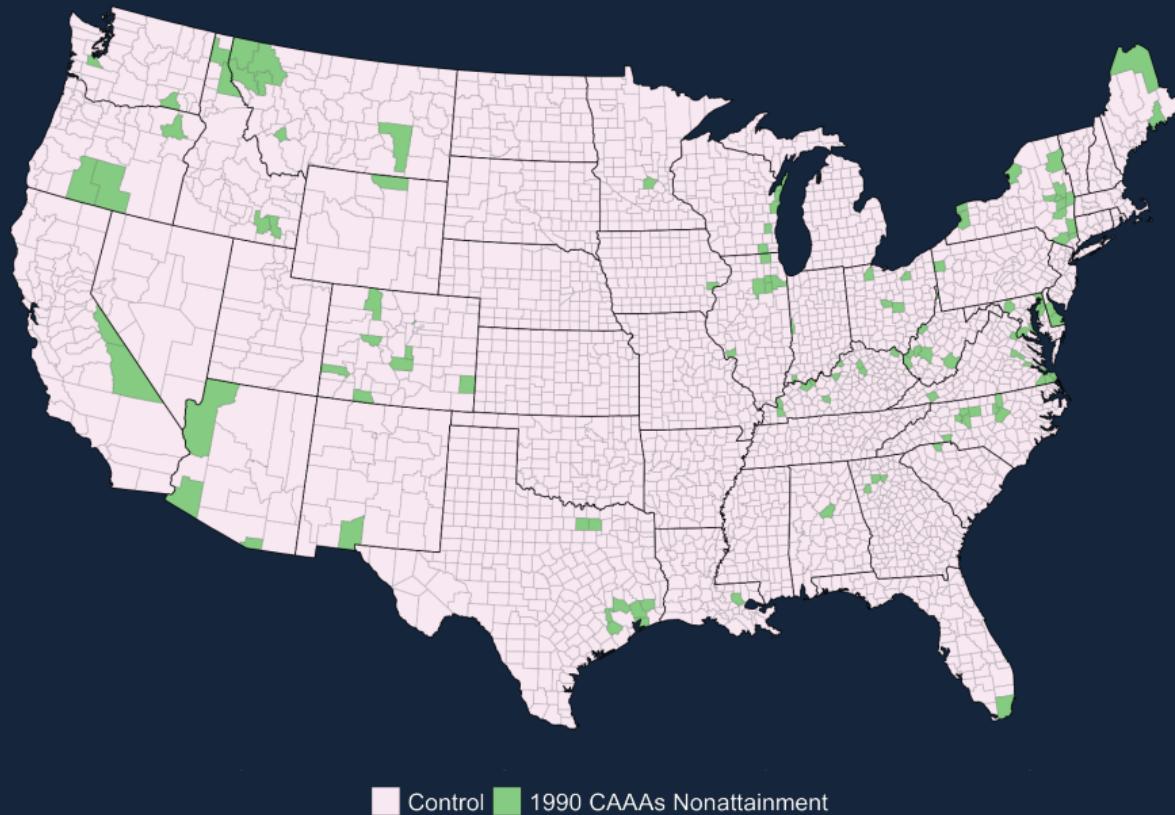
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This lead to the largest increase in nonattainment since the 1970s

Newly in nonattainment



Difference-in-differences

Compare manufacturing emissions in (new) nonattainment vs attainment counties, before vs after post-1990 CAAAs nonattainment designations

$$\log(e_{i,t}^p) = -\beta_\eta^p N_{i,t} + \log(w_{i,t} L_{i,t}) + \psi_i + \nu_{p,t} + \varepsilon_{i,t}^p$$

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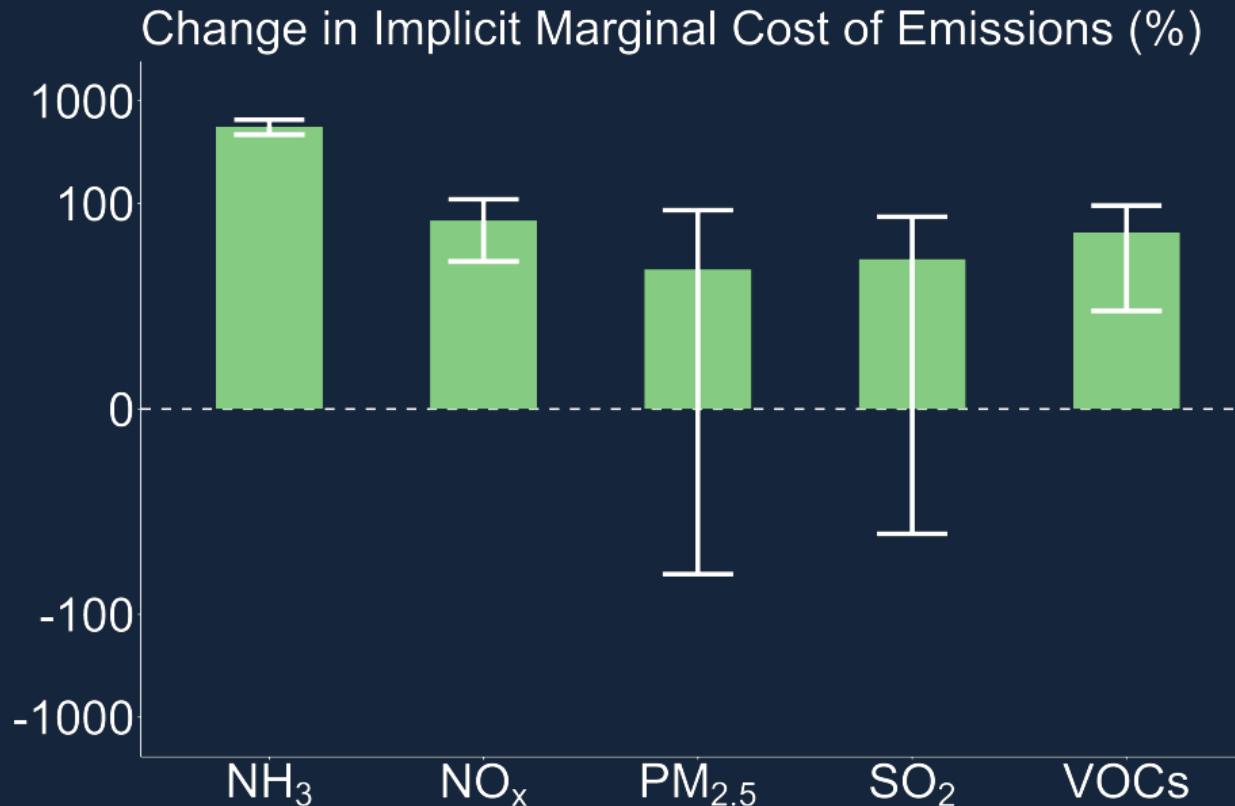
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Estimate the model using NEI data in 1990, 1996-2001 (no event studies)

Large increases in MC of $\text{PM}_{2.5}$ precursors



Model continued: Productivity

$$q_i^k = \left[\prod_{p=1}^P (e_i^{kp})^{\xi^{kp}} \right] [z_i^k (K_i^k)^{1-\gamma} (L_i^k)^\gamma]^{1 - \sum_{p=1}^P \xi^{kp}}$$

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We let $T_i^k = \bar{T}_i^k \exp(\beta_T^k N_i)$, where \bar{T}_i^k captures other sources of productivity

$\beta_T^k = 0$ for the non-polluting sector

The effect on productivity

Market clearing gives us equilibrium industry income:

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Industry income increases in: base productivity

Triple difference

Compare manufacturing vs nonmanufacturing income, in attainment vs nonattainment counties, before vs after post-1990 CAAAs nonattainment designations (Walker, 2013)

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Nonattainment reduces productivity

$\beta_T^k - \theta^k \sum_{p=1}^P \eta^{kp} \beta_\eta^p$	-0.074** (0.031)	-0.059** (0.026)	-0.099** (0.049)	-0.091** (0.036)
Observations	72,279	72,279	72,279	72,279
Ind-County / Ind-Year FEs	Yes	Yes	Yes	Yes
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Real wage control matters: implies SUTVA issues for non-spatial equilibrium models of the DGP

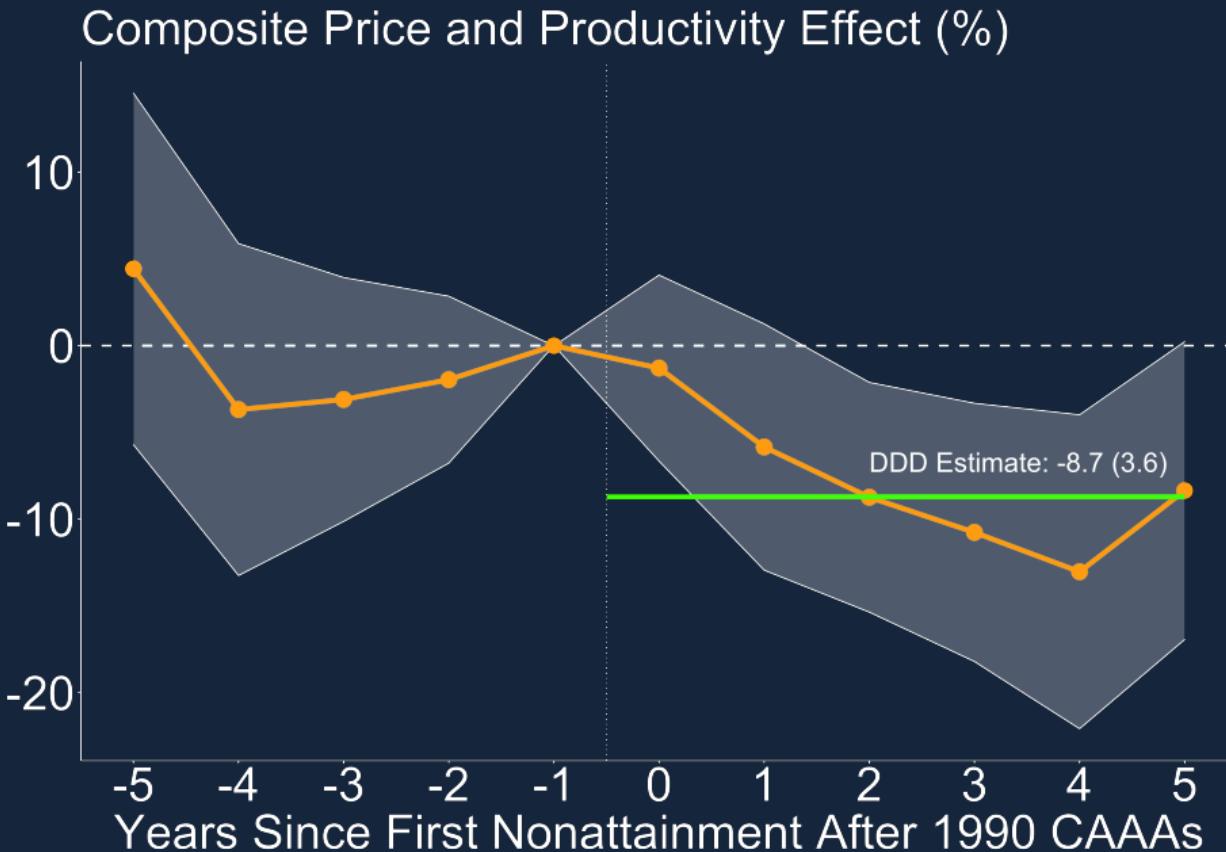
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Preferred estimate gives $\hat{\beta}_T^k = -0.05$ with nonparametric p-value of 0.096

The effect on productivity



Model: Household objective

$$U_j^m = \max_{i \in N, k \in K} B_i \delta_{ji}^{mk} \prod_{l=1}^K (C_i^l)^{\alpha^l}$$

Mass L_j^m of households in location $j = 1, \dots, N$ and industry $m = 1, \dots, K$

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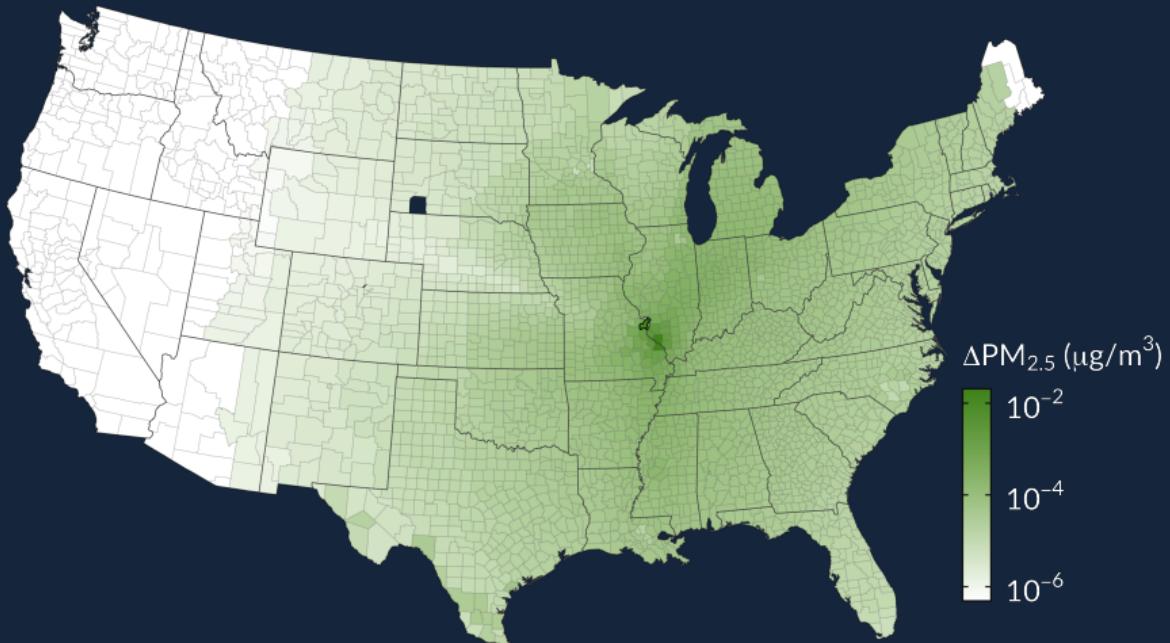
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Y_i is the atmospheric transport model from AP3

Model: 1000 tons of NO_x in St Louis



Model: Amenities

Local ambient pollution is mapped into dollar damages d_i using the AP3 dose-response functions:

$$d_i = D(y_i)$$

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Pollution transport + dose-response gives us marginal damages:

$$md_{ij} := \frac{\partial d_i}{\partial e_j} = \frac{\partial D(y_i)}{\partial y_i} \frac{\partial y_i}{\partial e_j}$$

Model: Amenities

The welfare cost for workers in market (i, k) in consumption equivalent terms is multiplicative (tractability):

$$B_i = \underbrace{\bar{B}_i}_{\text{non-pollution amenities}} \prod_{j=1}^N \underbrace{\left(1 - md_{ij}/C_i^k\right)^{e_j}}_{\text{consumption-equivalent damages}}$$

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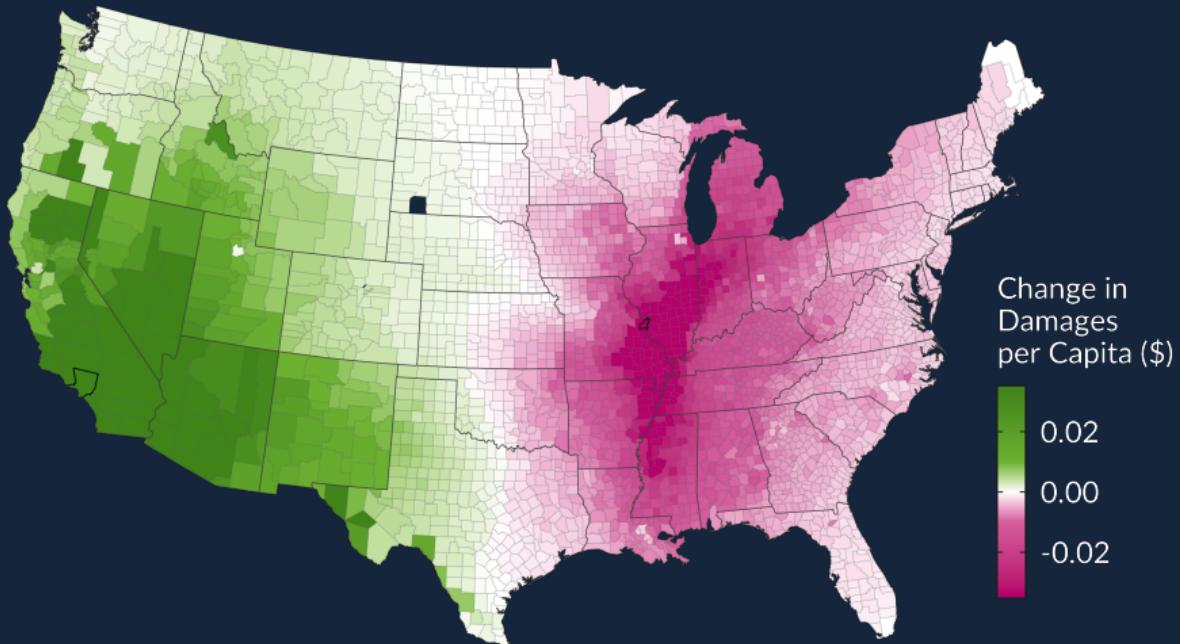
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Marginal damages in consumption-equivalent terms

Multiplicative expression ensures non-negative amenities

Model: Changing amenities

Relocate 1000 tons in St. Louis to Los Angeles



Model: Labor reallocation

» Do households respond to changes in amenities?

Moving from (j, m) to (i, k) incurs a utility cost $\delta_{ji}^{mk} \in (0, 1]$ where

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The share of households migrating from (j, m) to (i, k) is:

$$\pi_{ji}^{mk} = \frac{\frac{w_j^k}{P_i} B_i \bar{\delta}_{ji}^{mk}}{\sum_{n=1}^N \sum_{l=1}^K \frac{w_n^l}{P_n} B_n \bar{\delta}_{jn}^{ml}}$$

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What do we know from the model and empirical results?

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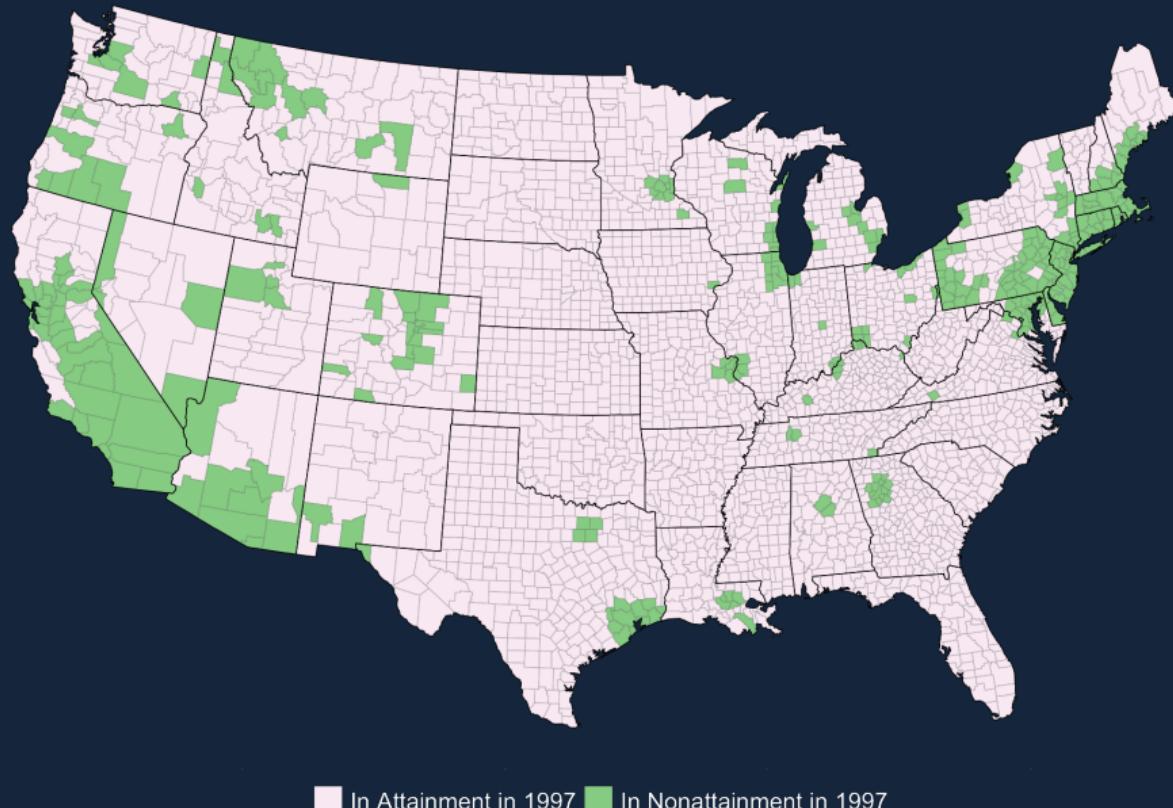
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The 1997 nonattainment shock



Aggregate welfare improvements are substantial

	Total		Amenity		Consumption	
	%	Billion \$	%	Billion \$	%	Billion \$
Aggregate	0.49	19.3	0.52	20.6	-0.03	-1.2
Manufacturing Sector	0.38	2.1	0.53	2.9	-0.17	-0.9
Nonmanufacturing Sector	0.51	17.1	0.52	17.6	-0.01	-0.3
Attainment Counties	0.21	3.9	0.17	3.2	0.03	0.6
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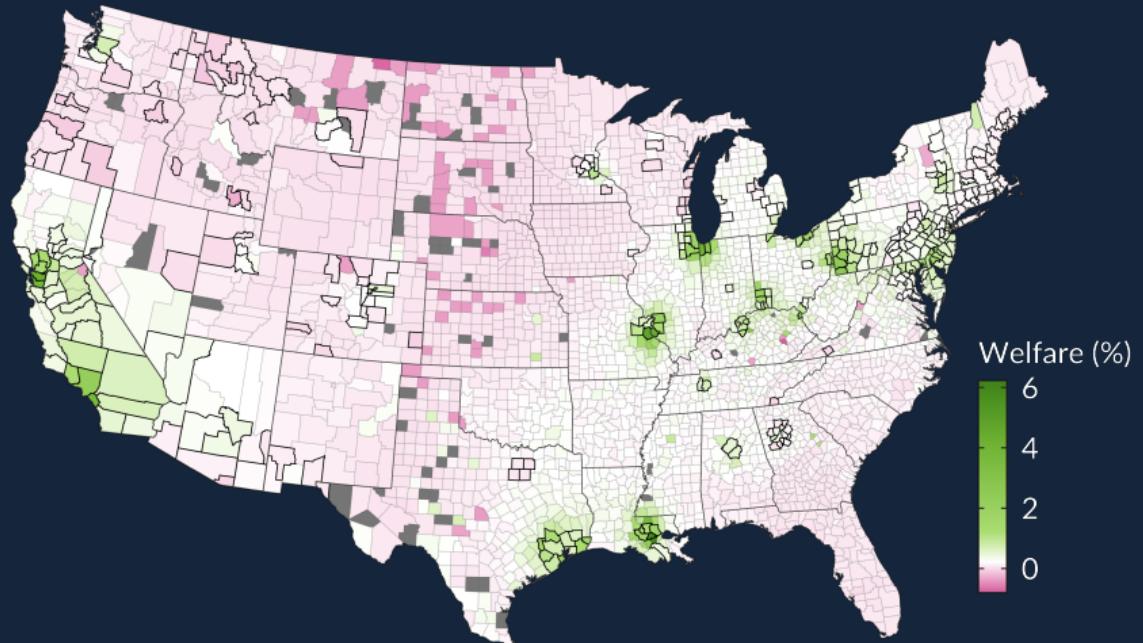
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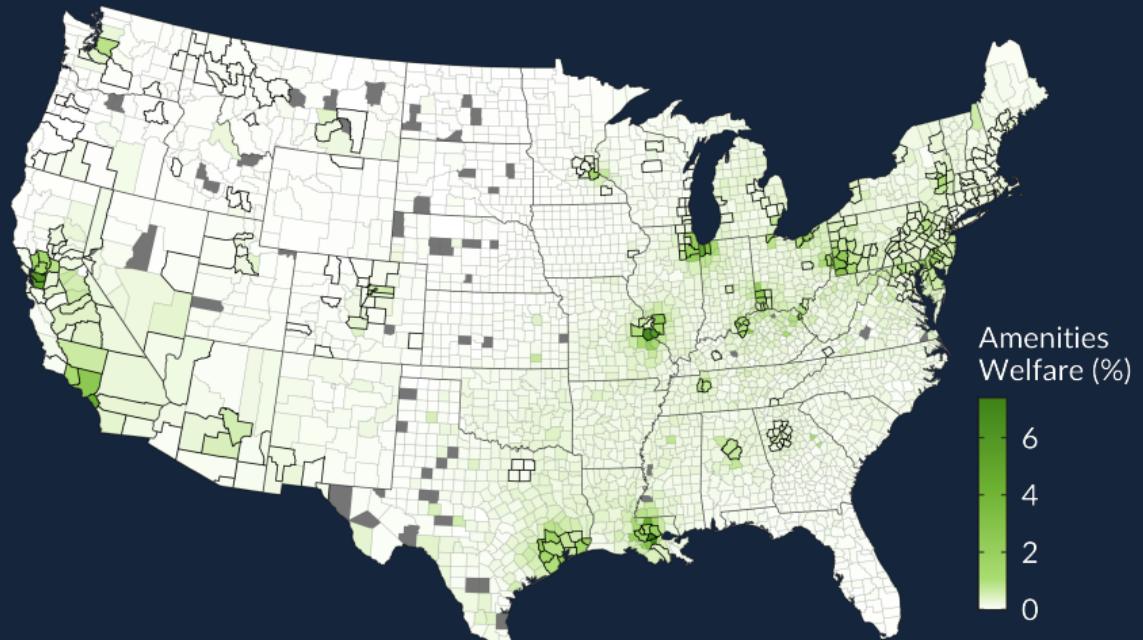
Significant spatial heterogeneity

Gains concentrated in major cities, labor and trade frictions matter



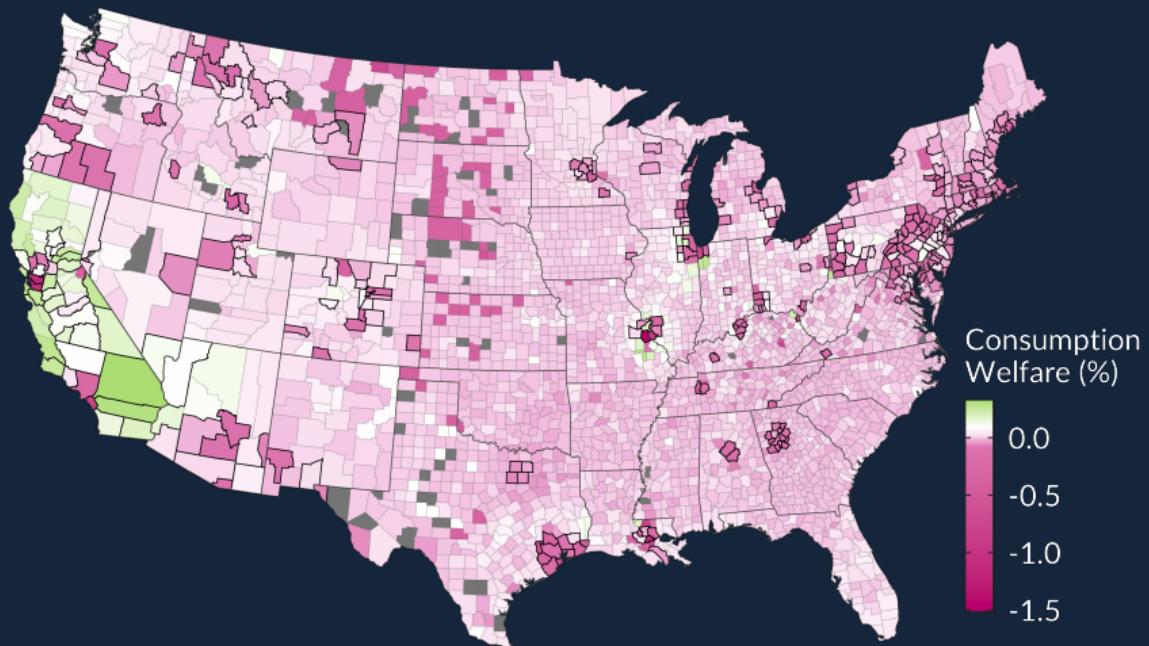
Amenities improve everywhere

Nonattainment emissions decline by up to 85% + small net *negative* leakage



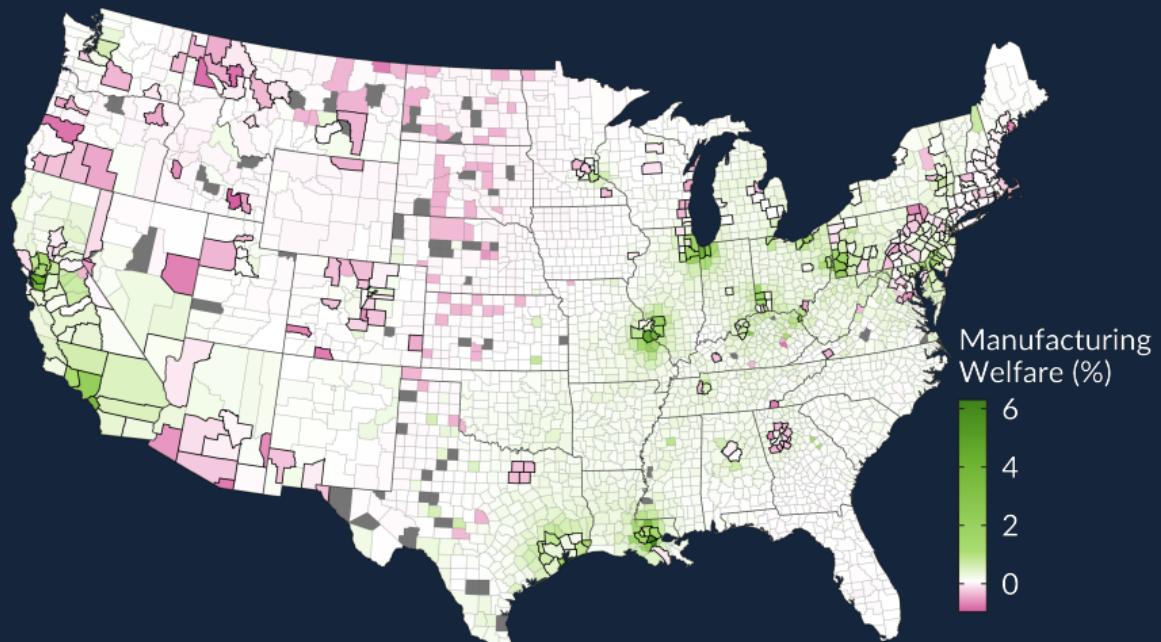
Losses are due to declining consumption

Higher prices and lower wages



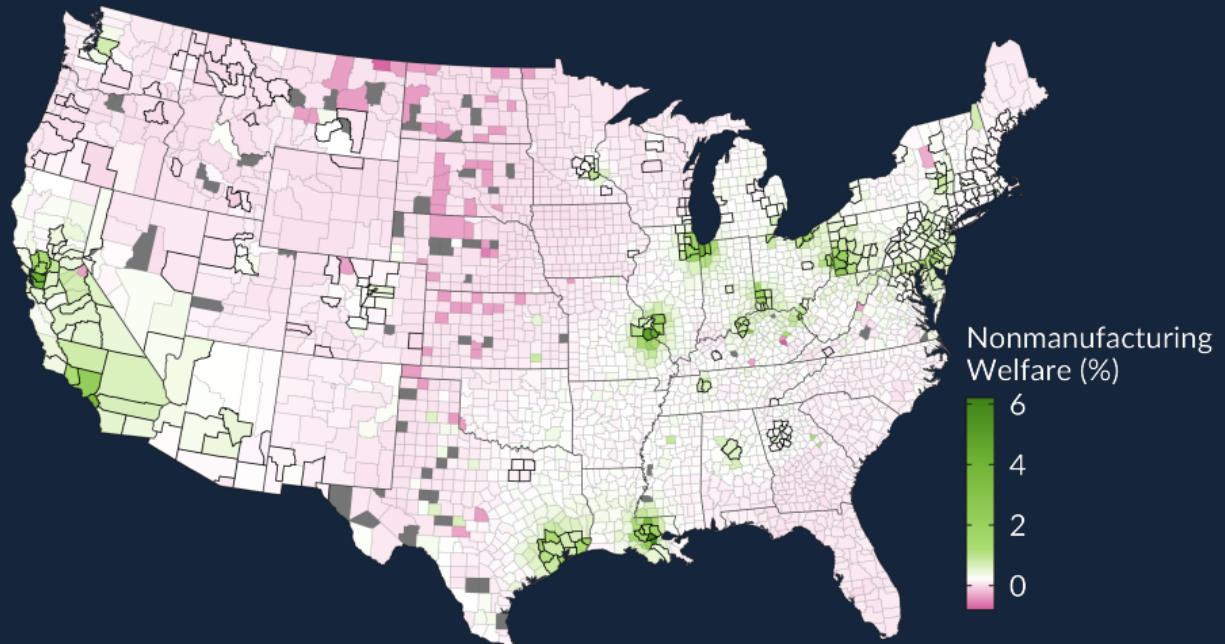
Nonattainment harms manufacturing

But nonattainment is welfare-enhancing for manufacturing in high emission areas



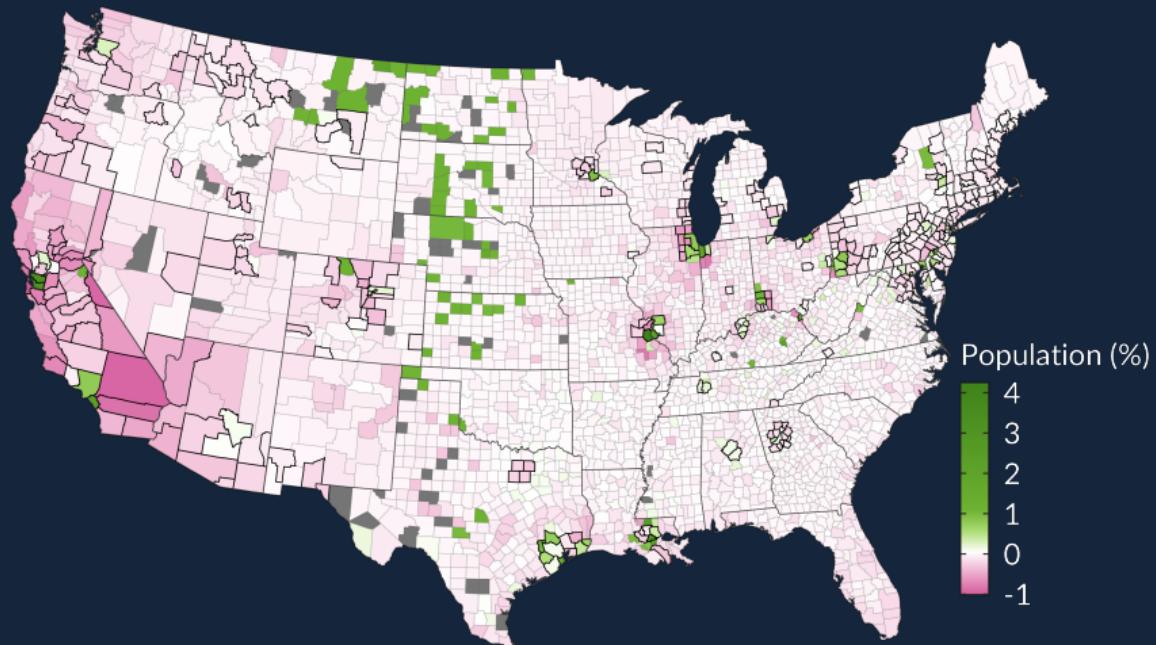
Nonattainment benefits nonmanufacturing

Real wage effect in nonattainment counties is much smaller for nonmanufacturing



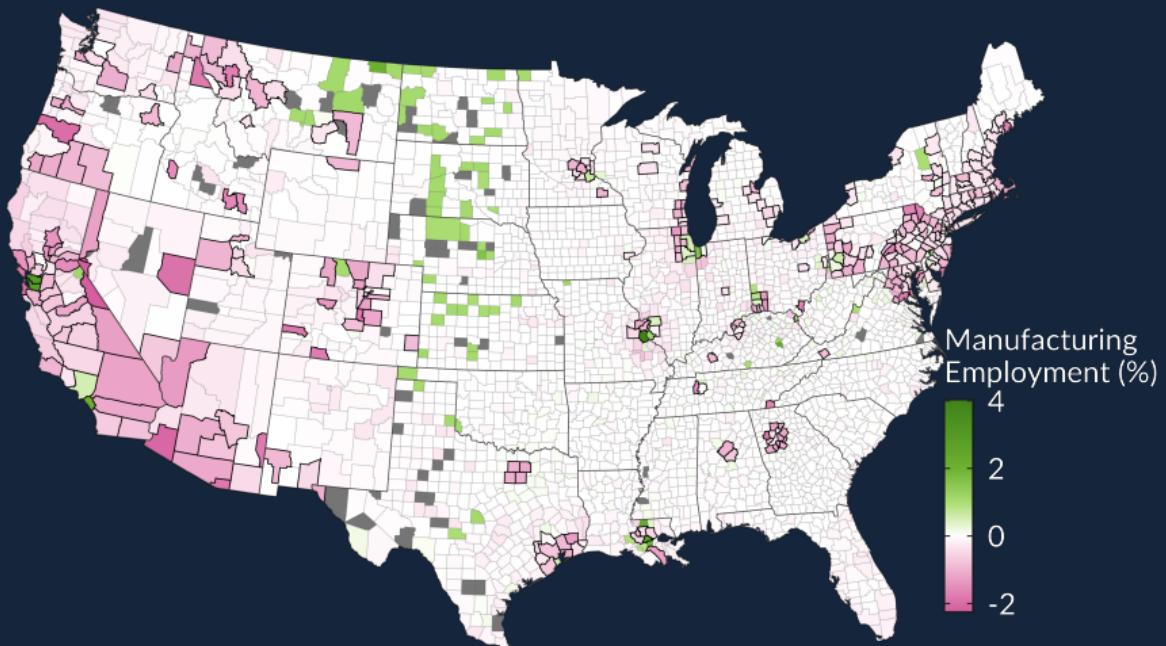
Labor reallocates across space

People leave nonattainment counties



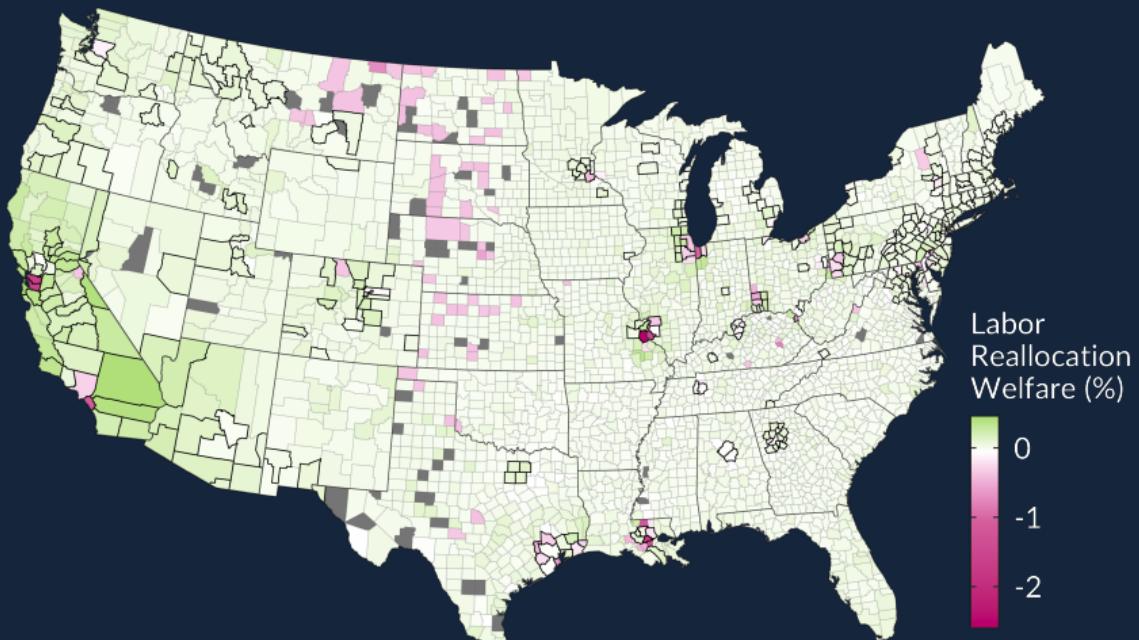
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Manufacturing exits nonattainment counties



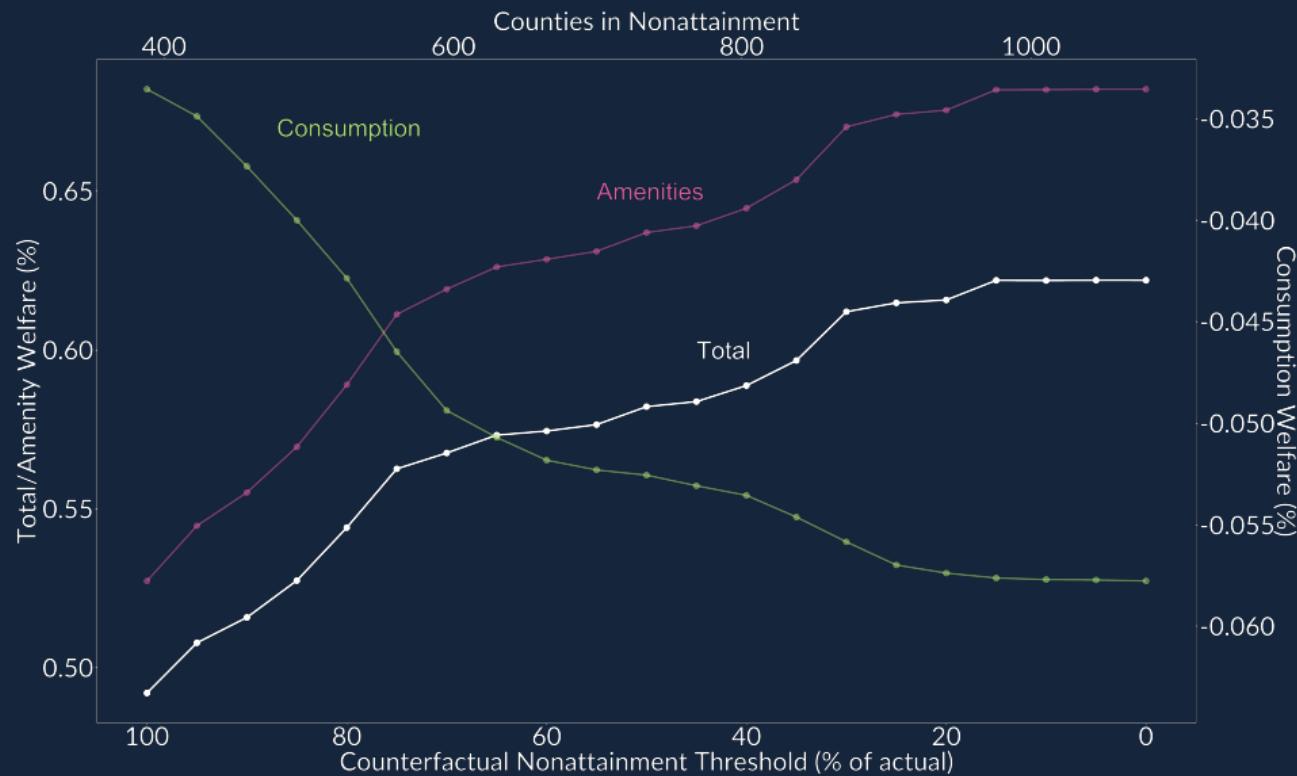
Heterogeneous benefits of labor reallocation

Aggregate effects: Consumption: +0.006pp, Amenities: -0.007pp



How stringent should nonattainment be?

20% tighter standard improves welfare by .05pp (\$2 billion / year)



Conclusions

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Missing pieces:

- Aggregation + no IO-links → costs underestimated
- Ignoring non-PM_{2.5} damages → benefits underestimated
- ► Reduced form amenities estimates

Reduced form amenities estimates

Back

Similar idea to Bayer et al. (2009) to deal with spatial frictions

Manipulate household migration shares to get:

$$\log\left(\frac{\pi_{ij}}{\pi_{ii}}\right) = \log\left(\frac{V_j B_j \delta_{jj}}{V_i B_i \delta_{ii}}\right) = \log\left(\frac{w_j/P_j}{w_i/P_i}\right) + \log(\delta_{jj}) + \log(\bar{B}_j/\bar{B}_i) + \beta_B (N_j - N_i)$$

where $\delta_{ii} = 1$

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where $\delta_{ii} = 1$

Amenities are common across workers so we use a DD estimator:

$$\log\left(\frac{\pi_{ij,t}}{\pi_{ii,t}}\right) = \beta_B (N_{j,t} - N_{i,t}) + \log\left(\frac{w_j/P_j}{w_i/P_i}\right) + \phi_{ij} + \nu_t + \varepsilon_{ij,t}$$

Households respond to nonattainment

▶ Back

Total amenities benefits are > 3%

	(1)	(2)	(3)	(4)
1(Dest. Nonattain) - 1(Orig. Nonattain)	0.040*** (0.013)	0.040*** (0.013)	0.034*** (0.013)	
1(Destination Nonattain)				0.034*** (0.013)
1(Origin Nonattain)				-0.033*** (0.013)
Observations	704506	704506	704506	704506
Origin-Destination FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Real Wage	Omitted	Coef. Free	Coef. Fixed	Coef. Fixed
Origin vs Destination	Fixed	Fixed	Fixed	Free