Valuing the environment: Measurement and Empirics II

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Plan for today

Costs of environmental regulation
- Greenstone (2002)
- Walker (2013)

Cost-benefit analysis
- Keiser and Shapiro (2019)

Costs of environmental regulation

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Economic output and environmental regulation

Last time, we estimated one aspect of $-D'(\cdot) = \theta$ for local air pollution, from

$$p_c = \theta t_c + \beta' x_c + \varepsilon_c,$$

using data on housing prices p_c and pollution t_c across counties c.

What about $\pi(\cdot)$?

$\hookrightarrow$ Use a similar research strategy to learn about some effects of the Clean Air Act on firm employment and output!

Key differences:

- different data (employment, revenue)
- have information about which pollutants which industries emit, so we should use that too
- simpler research design: the regulation itself is the independent variable of interest

Employment by pollution status

TABLE 2
MANUFACTURING EMPLOYMENT, BY POLLUTANT EMITTED AND POLLUTANT-SPECIFIC ATTAINMENT STATUS

	1967–72 (1)	1972–77 (2)	1977–82 (3)	1982–87 (4)
CO-emitting plants	1,111,534	1,040,563	951,515	744,061
CO attainment	1,111,534	839,456	648,526	517,767
CO nonattainment	...	201,108	302,989	226,294
O_3-emitting plants	5,453,418	5,581,151	5,542,548	5,412,151
O_3 attainment	5,453,418	5,108,078	1,294,500	1,492,627
O_3 nonattainment	...	473,073	4,248,048	3,919,524
SO_2-emitting plants	1,783,243	1,717,904	1,598,742	1,358,083
SO_2 attainment	1,783,243	1,468,781	1,233,592	1,170,479
SO_2 nonattainment	...	249,123	365,150	187,604
TSPs-emitting plants	2,101,561	2,071,924	1,899,173	1,697,843
TSPs attainment	2,101,561	1,303,442	1,114,749	1,160,430
TSPs nonattainment	...	768,482	784,424	537,413
Total manufacturing sector	17,438,187	17,350,726	17,521,355	17,100,413

NOTE.—See the note to table 1. Employment is the mean of total employment in the first and last years of each five-year period covered by the 1967–87 Censuses of Manufacturers.

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Pollution by industry

TABLE A2
ANNUAL INDUSTRIAL SECTOR POLLUTANT RELEASES BY INDUSTRY

Industry (SIC Code)	Carbon Monoxide Emissions (1)	Carbon Monoxide Share (2)	Nitrogen Dioxide Emissions (1)	Nitrogen Dioxide Share (2)	Volatile Organic Compounds Emissions (1)	Volatile Organic Compounds Share (2)	Sulfur Dioxide Emissions (1)	Sulfur Dioxide Share (2)	Total Suspended Particulates Emissions (1)	Total Suspended Particulates Share (2)	Emitter Status (3)
Metal mining (10)	5,391	.2%	28,583	1.6%	1,283	.1%	84,222	3.5%	140,052	15.4%	*
Nonmetal mining (14)	4,525	.1%	28,804	1.6%	1,736	.1%	24,129	1.0%	167,948	18.5%	*
Lumber and wood products (24)	123,756	3.5%	42,658	2.4%	41,423	3.0%	9,149	.4%	63,761	7.0%	TSPs
Wood furniture and fixtures (parts of 25)†	2,069	.1%	2,981	.2%	59,426	4.4%	1,606	.1%	3,178	.3%	Clean
Pulp and paper (2611–31)	624,291	17.5%	394,448	21.7%	96,875	7.1%	341,002	14.0%	113,571	12.5%	$CO/O_3/SO_2$/TSPs
Printing (2711–89)	8,463	.2%	4,915	.3%	101,537	7.5%	1,728	.1%	1,031	.1%	O_3
Inorganic chemicals (2812–19)	166,147	4.7%	108,575	6.0%	52,091	3.8%	182,189	7.5%	39,082	4.3%	SO_2
Organic chemicals (2861–69)	146,947	4.1%	236,826	13.0%	201,888	14.8%	132,459	5.4%	44,860	4.9%	O_3
Petroleum refining (2911)	419,311	11.8%	380,641	21.0%	309,058	22.7%	648,153	26.6%	36,877	4.1%	$CO/O_3/SO_2$
Rubber and miscellaneous plastic products (30)	2,090	.1%	11,914	.7%	140,741	10.3%	29,364	1.2%	5,355	.6%	O_3
Stone, clay, glass, and concrete (32)	58,043	1.6%	338,482	18.6%	30,262	2.2%	339,216	13.9%	171,853	18.9%	O_3/SO_2/TSPs
Iron and steel (3312–33, 3321–25)	1,518,642	42.6%	138,985	7.7%	82,292	6.0%	238,268	9.8%	83,017	9.1%	$CO/O_3/SO_2$/TSPs
Nonferrous metals (333–34)	448,758	12.6%	55,658	3.1%	27,375	2.0%	373,007	15.3%	22,490	2.5%	CO/SO_2
Fabricated metals (34)	3,851	.1%	16,424	.9%	102,186	7.5%	4,019	.2%	3,136	.3%	O_3
Electronics (36)	367	.0%	1,129	.1%	4,854	.4%	453	.0%	293	.0%	Clean
Motor vehicles, bodies, and parts (371)	35,303	1.0%	23,725	1.3%	101,275	7.4%	25,462	1.0%	12,853	1.4%	O_3
Dry cleaning (721)	101	.0%	179	.0%	7,310	.5%	152	.0%	28	.0%	*
Industrial sector total	3,568,055		1,814,927		1,361,612		2,434,578		909,385		

SOURCE.—EPA Sector Notebook Project (1995).

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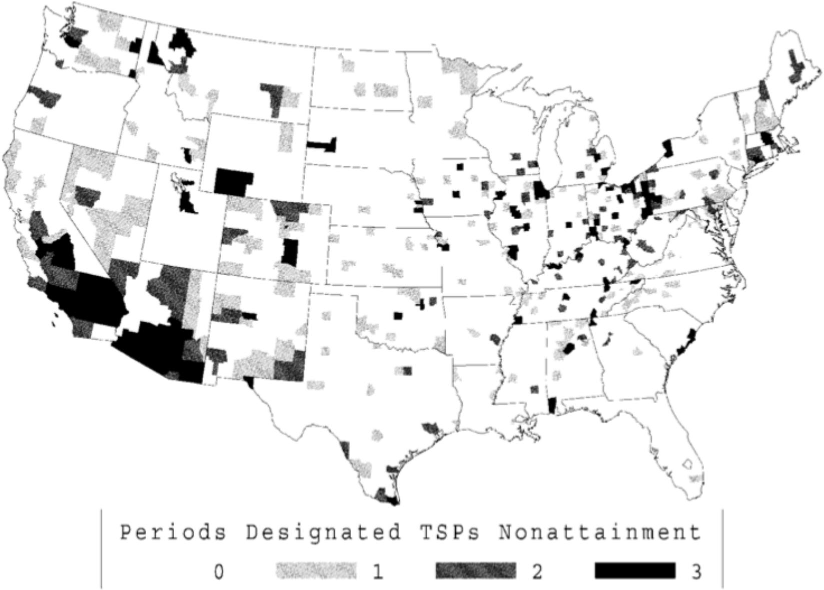
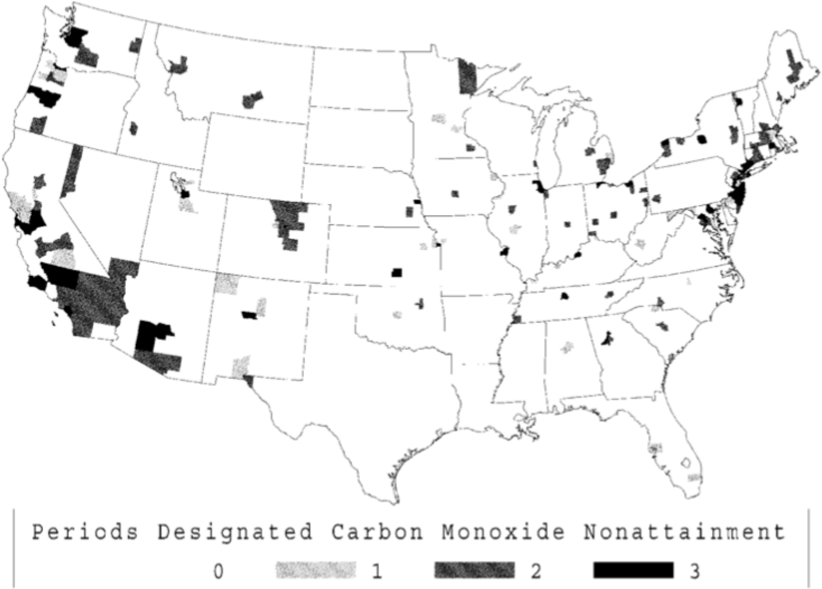
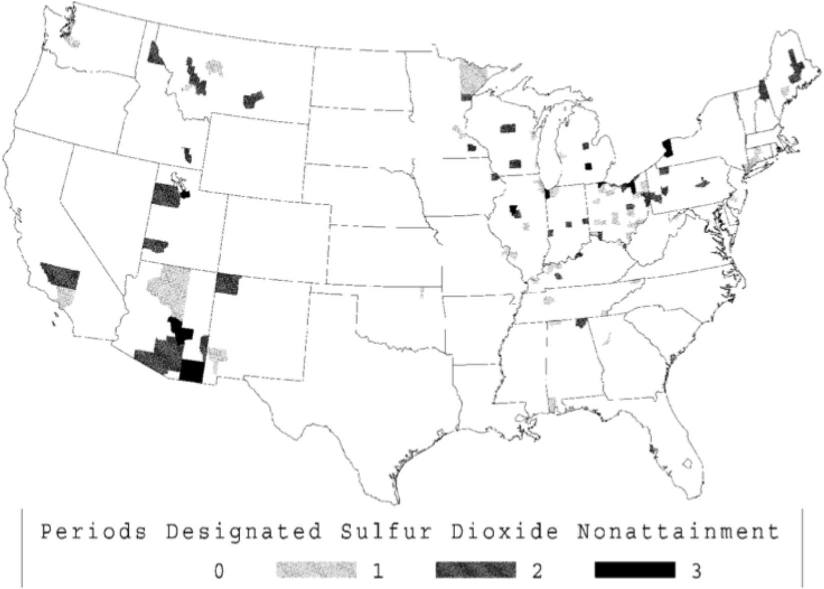
Nonattainment counties: TSP



Nonattainment counties: Carbon monoxide



Nonattainment counties: Sulfur dioxide



Empirical framework

Notation:

- y_{ct} be changes in output or employment in county c, period t
- z_{ct} be an indicator for Clean Air Act nonattainment status
- x_{ct} be various controls

The statistical relationship is given by

$$y_{ct} = \theta z_{ct} + \beta' x_{ct} + \varepsilon_{ct}$$

where θ is the coefficient of interest.

Our θ gives a causal relationship if nonattainment status, z_{ct}, is as good as randomly assigned to counties, conditional on the controls (i.e., $\mathbb{E}[z_{ct}\varepsilon_{ct}|x_{ct}] = 0$).

Greenstone (2002) allows θ to vary across industry and pollution type $\hookrightarrow$

Effect of regulation on employment

TABLE 5
ESTIMATED REGRESSION MODELS FOR THE PERCENTAGE CHANGE IN EMPLOYMENT

	(1)	(2)	(3)	(4)
CO regulation effect (β_4)	−.084	−.075	−.086	−.163
	(.032)	(.031)	(.030)	(.045)
O_3 regulation effect (β_5)	.001	.022	−.011	−.049
	(.011)	(.010)	(.010)	(.015)
SO_2 regulation effect (β_6)	−.004	−.016	.003	.001
	(.029)	(.028)	(.029)	(.036)
TSPs regulation effect (β_7)	−.024	−.010	−.020	−.024
	(.014)	(.013)	(.013)	(.024)
R^2	.109	.119	.144	.504
Industry by period fixed effects	yes	yes	yes	yes
Nonattainment by period fixed effects	yes	yes	no	no
County fixed effects	no	yes	no	no
County by period fixed effects	no	no	yes	yes
Plant fixed effects	no	no	no	yes

NOTE.—See the note to table 4. In all specifications, the sample includes the 1,620,942 plant observations with nonmissing and nonnegative employment levels. The mean five-year growth rate of employment in the sample is −1.4 percent.

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Effect of regulation on capital and output

TABLE 6
ESTIMATED REGRESSION MODELS FOR THE PERCENTAGE CHANGE IN CAPITAL STOCK AND SHIPMENTS

	(1)	(2)	(3)	(4)
	A. Capital Stock (N=1,607,332)			
CO regulation effect (β_4)	−.047	−.047	−.097	−.092
	(.043)	(.042)	(.043)	(.062)
O_3 regulation effect (β_5)	−.009	.016	−.001	−.041
	(.022)	(.021)	(.021)	(.029)
SO_2 regulation effect (β_6)	−.024	−.048	−.057	−.063
	(.047)	(.049)	(.055)	(.048)
TSPs regulation effect	.026	.042	.010	−.043
(β_7)	(.027)	(.025)	(.024)	(.039)
R^2	.074	.109	.155	.462
	B. Shipments (N=1,737,753)			
CO regulation effect (β_4)	−.058	−.036	−.072	−.146
	(.029)	(.029)	(.029)	(.046)
O_3 regulation effect (β_5)	.022	.048	.019	−.032
	(.018)	(.018)	(.016)	(.024)
SO_2 regulation effect (β_6)	−.007	−.026	−.027	−.010
	(.033)	(.030)	(.030)	(.039)
TSPs regulation effect	−.014	−.002	−.010	−.032
(β_7)	(.019)	(.018)	(.018)	(.034)

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Total costs

TABLE 9
TWO MEASURES OF THE MAGNITUDE OF THE REGULATION EFFECTS

	Estimated Regulation-Induced Change, 1972–77 to 1982–87		Change 1972–77 to 1982–87	Mean of 1972–77 and 1982–87 Levels	Ratio of Col. 1 to Col. 3	Ratio of Col. 1 to Col. 4
	Mean (1)	95% Confidence Interval (2)	(3)	(4)	(5)	(6)
	A. Total Employment					
CO emitters	−119,100	[−54,600, −183,500]	−296,502	892,312	.402	−.133
O_3 emitters	−423,400	[−169,400, −677,400]	−169,000	5,496,651	2.505	−.077
SO_2 emitters	800	[57,400, −55,800]	−359,821	1,537,994	−.002	.001
TSPs emitters	−50,200	[48,200, −148,500]	−374,081	1,884,883	.134	−.027
All manufacturers	−591,900	[−118,400, −1,065,200]	−250,183	17,215,016	2.366	−.034

Total costs

TABLE 9
Two Measures of the Magnitude of the Regulation Effects

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Bottom line

Substantial effects on employment:

- e.g., industries emitting carbon monoxide (CO) saw 119,100 fewer jobs in the first 15 years due to the Clean Air Act

In total, nonattainment counties (relative to attainment ones)

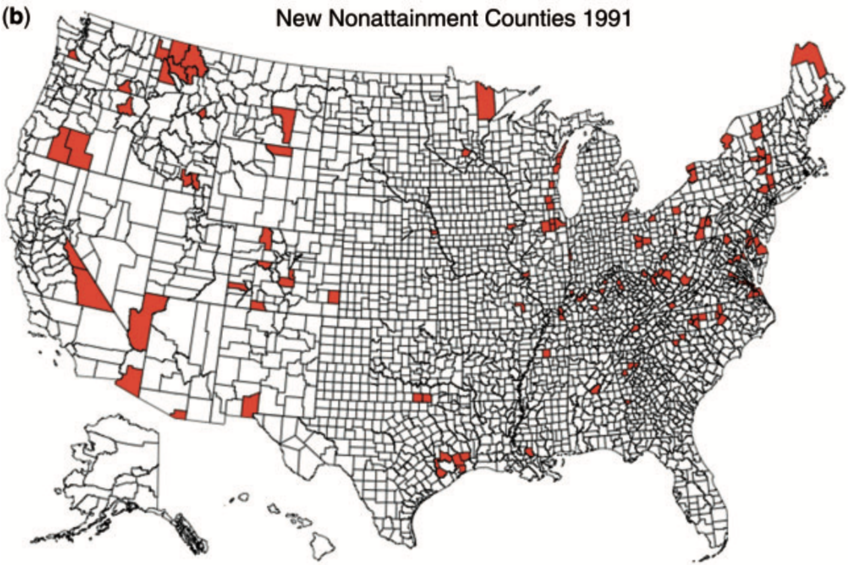
- lost approximately 590,000 jobs,
- $37 billion in capital stock, and
- $75 billion of output in polluting industries

Jobs and environmental regulation

Walker (2013) uses a related research design with detailed worker-level data to ask what happens to workers in regulated industries.

Studies the 1990 amendments to the Clean Air Act. $\hookrightarrow$

1990 Clean Air Act Amendments



Jobs and environmental regulation

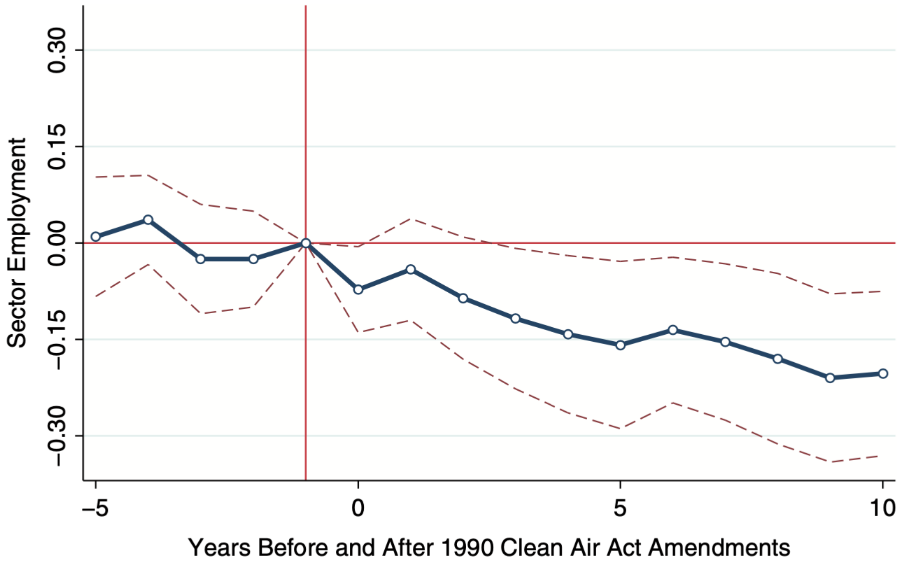
Empirical framework uses an **event study** regression design, which traces the effect of a policy change over time:

$$y_{ct} = \sum_{k=-m}^{M} \theta_k z_{c,t+k} + \beta' x_{ct} + \varepsilon_{ct},$$

where

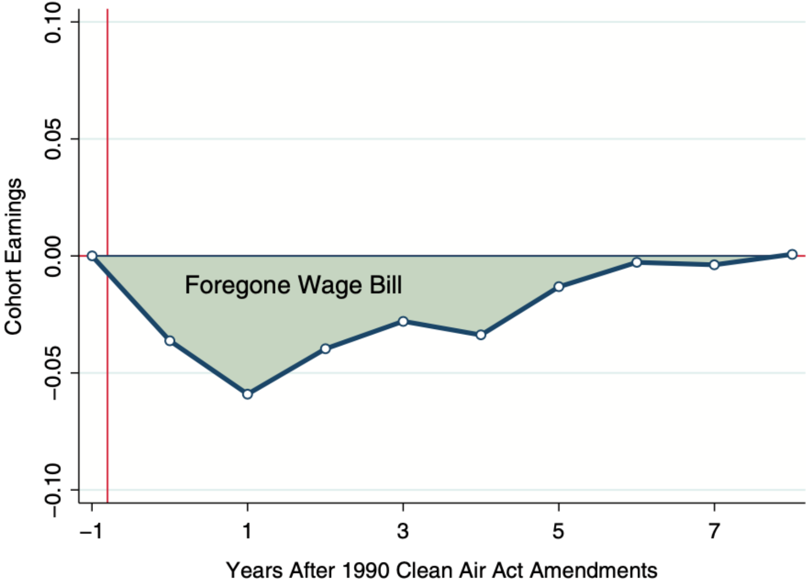
- the coefficients, $(\theta_k)_{k=-m}^{M}$, are indexed by time from treatment k, and
- $z_{c,t+k}$ is an indicator variable that equals 1 if county c experienced a policy change by $t+k$, and 0 otherwise.

Effect of environmental regulation on workers

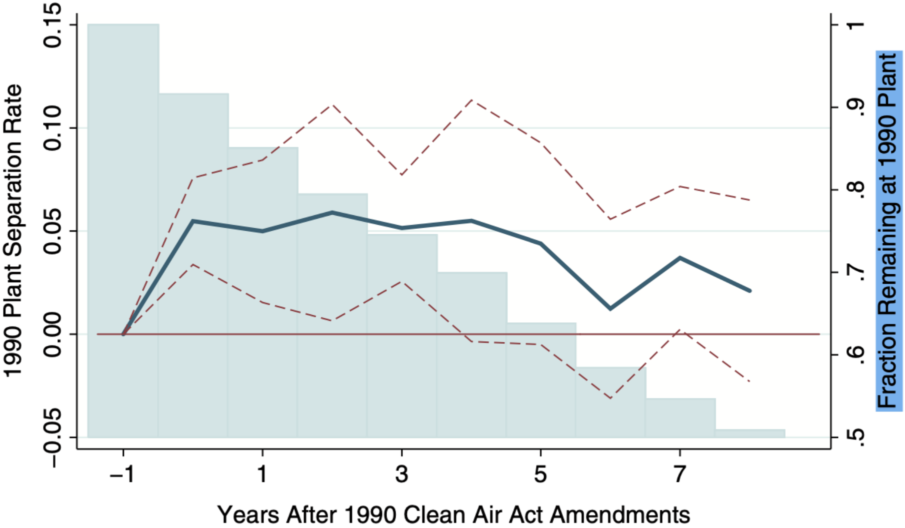


Plot of $\hat{\theta}_k$, with k on the x-axis.

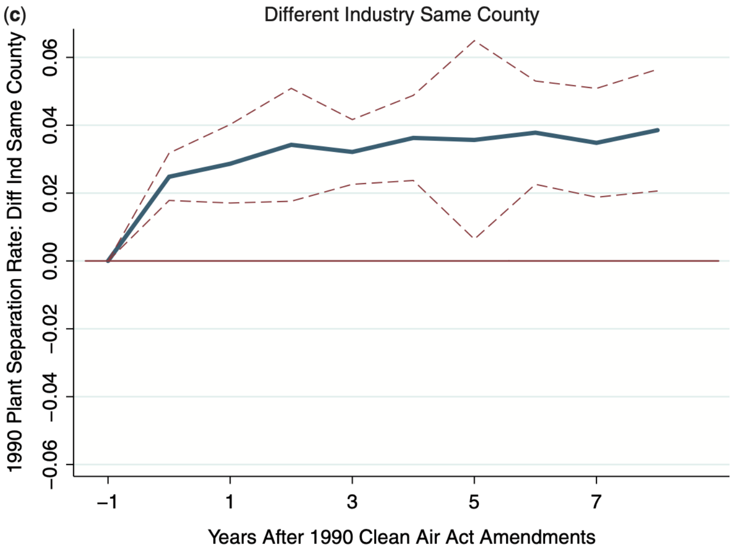
Cumulative lost earnings



Where do workers go?



Most transition to different industries in the same county



Bottom line

Walker finds:

- The average worker in a newly regulated plant experiences a present discounted earnings loss of around 20% of their preregulatory earnings.
- In aggregate, this amounts to almost **$5.4 billion** in forgone earnings.

Costs of environmental regulation
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- Walker (2013)

Cost-benefit analysis
- Keiser and Shapiro (2019)

Clean Water Act

Keiser and Shapiro (2019)

Question: what were the costs and benefits of the 1972 Clean Water Act?

Importance:

- water is essential to life
- $650 billion grants for wastewater treatment from 1972–2001

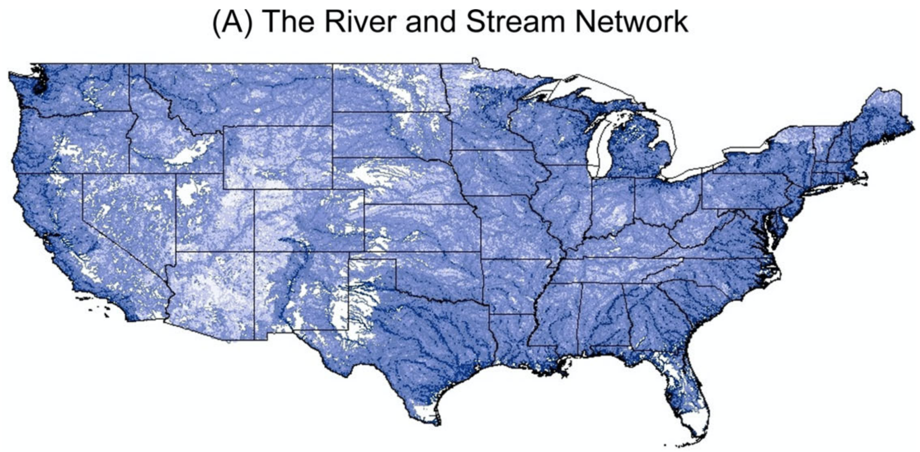
Approach:

- new data on Clean Water Act grants, water pollution, home values
  - 35,000 grants
  - 180,000 monitoring sites; 200 million pollution readings
  - Census tract housing data, 1970–2000
- event study framework

Hyperion Water Reclamation Plant, Santa Monica Bay

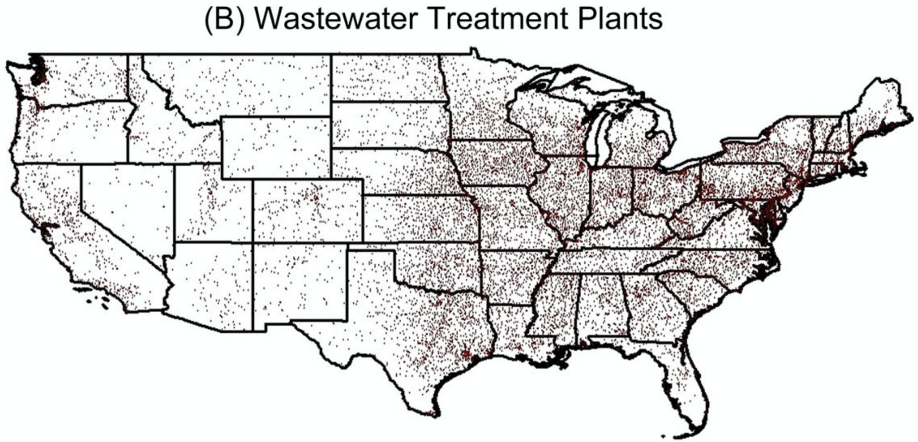
Ballona Creek, Marina Del Rey, 9 October 2022

U.S. river network



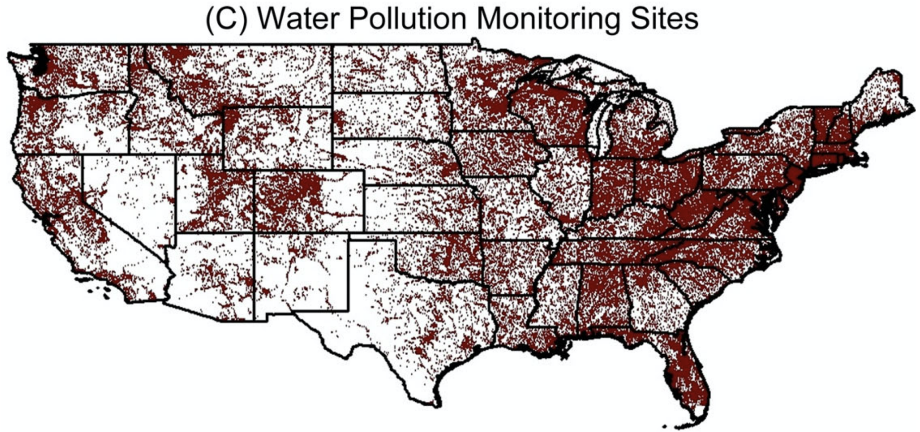
Source: Keiser and Shapiro (2019, Figure 1)

Pollution abatement



Source: Keiser and Shapiro (2019, Figure 1)

Pollution monitoring



Source: Keiser and Shapiro (2019, Figure 1)

Water quality improves over time

Water Pollution

	Main pollution measures	
	Dissolved oxygen deficit (1)	Not fishable (2)
Panel A: Linear trend		
Year	–0.240***	–0.005***
	(0.0296)	(0.0003)
Panel B: 1972 trend break		
Year	–1.027***	–0.015***
	(0.147)	(0.002)
Year* 1[Year>=1972]	0.834***	0.011***
	(0.157)	(0.002)
1972 to 2001 change	–5.583	–0.118
	(0.902)	(0.009)
N	5,852,148	10,969,154
Dep. var. mean	17.78	0.25
Monitor fixed effects	Yes	Yes
Season controls	Yes	Yes
Time of day controls	Yes	Yes

Water quality improves over time

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Water quality improves more slowly after 1972...

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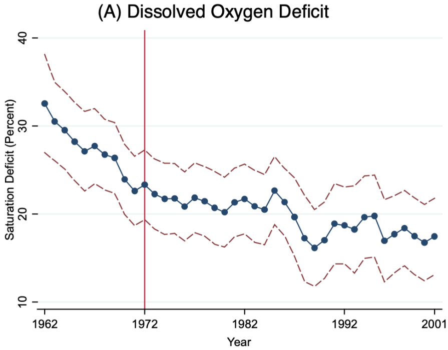

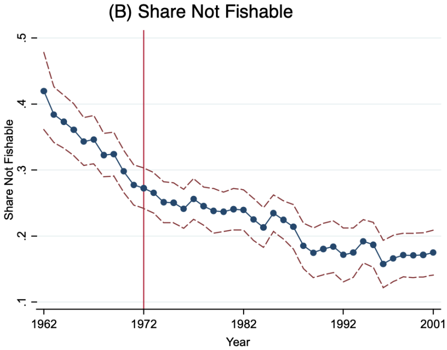

Empirical framework

Define

- y_{it} is the water pollution reading at treatment plant i in year t
- z_{it} is the cumulative number of grants the plant received by t
- x_{it} are controls for temperature, precipitation, permanent plant effects, location in the river network, etc.

Then the statistical relationship of interest is

$$y_{it} = \theta z_{it} + \beta' x_{it} + \varepsilon_{it}$$

which corresponds to a causal effect if $\mathbb{E}[z_{it}\varepsilon_{it}|x_{it}] = 0$.

Water Act grants improve average water quality

EFFECTS OF CLEAN WATER ACT

	Main pollution measures	
	Dissolved oxygen deficit (1)	Not fishable (2)
Downstream *Cumul. # grants	−0.681***	−0.007**
	(0.206)	(0.003)
N	55,950	60,400
Dep. var. mean	17.092	0.328
Fixed effects:		
Plant-downstream	Yes	Yes
Plant-year	Yes	Yes
Downst.-basin-year	Yes	Yes
Weather	Yes	Yes

Notes. Each observation in a regression is a plant-downstream-year tuple.

Water Act grants improve average water quality

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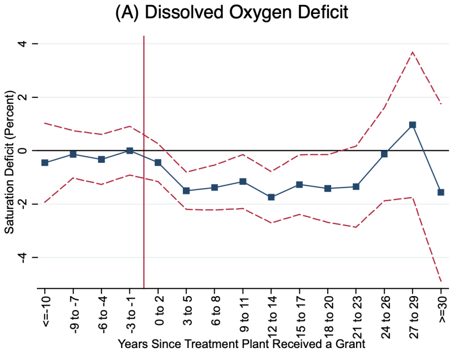

Coefficients θ_k from the event study, $y_{it} = \sum_{k=-m}^{M} \theta_k z_{it} + \beta' x_{it} + \varepsilon_{it}$.

Cost-effectiveness

TABLE III

COST-EFFECTIVENESS OF CLEAN WATER ACT GRANTS ($2014 MN)

	(1)	(2)	(3)
1. Total costs	296,757	396,802	549,890
2. Federal capital costs	87,926	117,691	164,413
3. Local capital costs	37,296	49,958	68,309
4. Operation maintenance costs	171,536	229,153	317,168
5. River miles made fishable	5,188	9,000	12,260
6. River miles * pct. saturation increase/10	14,721	25,536	34,787
7. Annual cost to make a river-mile fishable	1.91	1.47	1.50
	[1.35 , 3.22]	[1.04 , 2.48]	[1.06 , 2.53]
8. Annual cost to increase dissolved oxygen saturation in a river-mile by 10%	0.67	0.52	0.53
	[0.42 , 1.65]	[0.33 , 1.27]	[0.33 , 1.29]
Plants with water quality data	Yes		
Georeferenced plants		Yes	
Assume 25 miles downstream			Yes

Notes. Dollar values in $2014 millions. Brackets show 95% confidence intervals.

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Water Act grants and housing value

Similarly, for housing values p_{it}, we aim to estimate θ from

$$p_{it} = \theta z_{it} + \beta' x_{it} + \varepsilon_{it}.$$

Alternatively, with an event study, we estimate $(\theta_k)_{k=-m}^{M}$ from

$$p_{it} = \sum_{k=-m}^{M} \theta_k z_{i,t+k} + \beta' x_{it} + \varepsilon_{it}.$$

Water Act grants and average housing value

TABLE V

EFFECTS OF CLEAN WATER ACT GRANTS ON HOUSING DEMAND

	(1)	(2)	(3)	(4)
Panel A: Log mean home values				
Cumulative grants	−0.00022	0.00076	0.002486*	0.00024
	(0.002507)	(0.001409)	(0.001271)	(0.000328)
Panel B: Log mean rental values				
Cumulative grants	0.00005	−0.00078	0.00007	−0.00012
	(0.001682)	(0.000832)	(0.000714)	(0.000158)
Panel C: Log total housing units				
Cumulative grants	−0.006965**	−0.00031	−0.00031	−0.00016
	(0.003180)	(0.001176)	(0.000939)	(0.000241)
Panel D: Log total value of housing stock				
Cumulative grants	−0.006356*	0.00010	0.00144	−0.00015
	(0.003275)	(0.001878)	(0.001592)	(0.000461)
Plant FE, basin-by-year FE	Yes	Yes	Yes	Yes
Dwelling characteristics		Yes	Yes	Yes
Baseline covariates * year		Yes	Yes	Yes
Max distance homes to river (miles)	0.25	0.25	1	25

Water Act grants and average housing value

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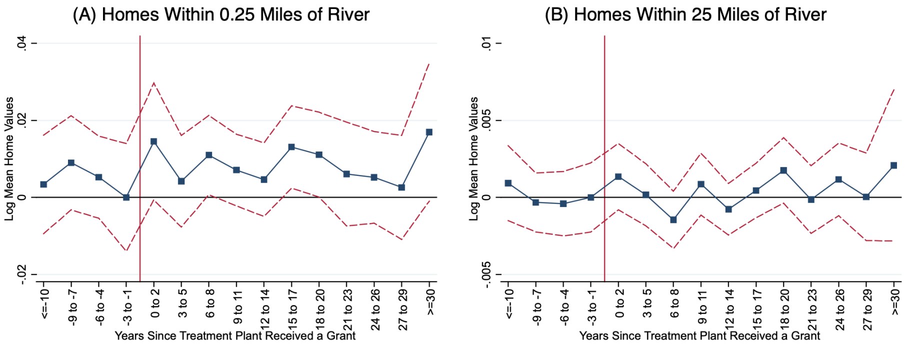
Water Act grants and housing value over time



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Costs v. benefits with home values

TABLE VI

CLEAN WATER ACT GRANTS: COSTS AND EFFECTS ON HOME VALUES ($2014BN)

	(1)	(2)	(3)	(4)
Ratio: Change in home values/costs	0.06	0.26	0.22	0.24
	(0.03)	(0.36)	(0.36)	(0.41)
p-value: ratio = 0	[0.05]	[0.46]	[0.55]	[0.56]
p-value: ratio = 1	[0.00]	[0.04]	[0.03]	[0.06]
Change in value of housing ($Bn)	15.92	89.25	73.7	91.97
Costs ($Bn)				
Capital: fed.	86.24	102.26	102.26	114.16
Capital: local	35.81	41.81	41.81	48.00
Variable	166.1	197.36	197.36	222.81
Total	288.15	341.44	341.44	384.97
Max distance homes to river (miles)	1	25	25	25
Include rental units			Yes	Yes
Include nonmetro areas				Yes

Costs v. benefits with home values

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p-value: ratio = 0	[0.05]	[0.46]	[0.55]	[0.56]
p-value: ratio = 1	[0.00]	[0.04]	[0.03]	[0.06]
Change in value of housing ($Bn)	15.92	89.25	73.7	91.97
Costs ($Bn)				
Capital: fed.	86.24	102.26	102.26	114.16
Capital: local	35.81	41.81	41.81	48.00
Variable	166.1	197.36	197.36	222.81
Total	288.15	341.44	341.44	384.97
Max distance homes to river (miles)	1	25	25	25
Include rental units			Yes	Yes
Include nonmetro areas				Yes

Recap

Three empirical approaches:

1. use changes in pollution caused by regulation to estimate the value of lowering pollution from market prices for housing
2. use changes in employment caused by regulation to estimate the costs of meeting environmental goals
3. use staggered changes in regulation or subsidies over time to study the costs and benefits of environmental policy

Common goal: disentangle causation from correlation by focusing on **narrow** comparisons between **otherwise similar** groups

Next time

- Solutions for the first problem set posted later tonight
- Past midterms (for practice) posted earlier today
- On Wednesday, last lecture on fundamentals of environmental economics: common-pool externalities and public goods!