Economics 134 L11. Markets for pollution

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Announcement

To accommodate students with travel plans, I am moving the Wednesday lecture of Thanksgiving week (11/26) to **Zoom**.

Link will be on the website.

Designing a market for pollution ("cap-and-trade")

Case study. Air pollution trading under RECLAIM

Markets for pollution

Many environmental problems arise from the sum of a large number of actions undertaken by different individuals or firms.

For example,

- carbon emissions from more than 100 different countries
- depletion of a groundwater reservoir by a large number of farmers
- pollution generated by thousands of firms regulated under **the Clean Air Act**

For these problems, so far, we have only contrasted the free market outcome with the first-best (or efficient) outcome.

We will now define another approach, known as "**command-and-control**." This is, historically, the approach taken by environmental law.

Command-and-control

To be concrete, suppose we have $N \geq 2$ firms. Each firm chooses some level of production q_i, which creates negative environmental externalities.

Suppose each have profits

$$\pi_i(q) = p \cdot q - \frac{c_i}{2} q^2$$

where c_i is firm i's cost.

A1. Only aggregate output matters for environmental damage, $D(\sum_{i=1}^{N} q_i)$, with $D', D'' > 0$ as usual.

A2. Some firms are more efficient than others; let

$$c_1 < c_2 \leq \cdots \leq c_N.$$

Remark 1. Equivalently, we could have all firms with the same cost, but some firms sell for higher prices (e.g., produce more valuable products!) than others.

Command-and-control, cont'd

As usual, the first-best solves

$$p - c_i q_i^{\mathrm{FB}} - D'(\cdot) = 0,$$

so that each i should produce

$$q_i^{\mathrm{FB}} = \frac{p - D'(\cdot)}{c_i}.$$

where $D'(\cdot)$ is evaluated at $\sum_{i=1}^{N} q_i^{\mathrm{FB}}$.

In particular, $q_i^{\mathrm{FB}} < q_i^*$ (the free market outcome).

Definition (Command-and-control)

The "command-and-control" policy for the above problem specifies a pollution limit $\overline{q}$, and requires that no firm i exceed this limit, in order to maximize welfare.

Command-and-control, cont'd

Claim: under assumptions A1 and A2, the command-and-control policy is

1. strictly **better** than the free market outcome
2. strictly **worse** than the first-best outcome.

(So, we could call it "second-best.")

To see the first result, note that

- we can never do worse than q_i^* (just set $\overline{q} = +\infty$), and
- can always do a bit better by at least setting $\overline{q}$ a bit less than $\max_i q_i^*$.

To see the second result, note that

- for any $\overline{q}$ that restricts output,
- we could do slightly better by **reallocating** some production from a higher-cost firm to a lower-cost firm,
- to produce exactly the same overall pollution at lower cost!

Discussion

1. When firms are identical, there is no difference between the optimal command-and-control and the first-best!

2. When firms are different, then the gains from moving to the first-best from the second-best command-and-control can be **substantial**.
   - these benefits are not just profits, but also can (should) include **greater environmental protection**
     - ↪ when we lower the aggregate cost of meeting a given environmental objective by more efficiently allocating the cost across firms, we then desire more environmental protection!

3. Crucial that $D(\cdot)$ depends on the aggregate, not individual, actions.

4. We can implement the first-best with similar information as the command-and-control. We just need to know $Q^{\mathrm{FB}} = \sum_i q_i^{\mathrm{FB}}$.
   - Algorithm: issue exactly Q^{FB} credits to pollute (**cap**), then set up a competitive market where firms can **trade** the pollution credits.

Designing a market for pollution ("cap-and-trade")

Case study. Air pollution trading under RECLAIM

The Regional Clean Air Incentives Market (RECLAIM)

Context:

- Substantial air pollution in Los Angeles basin
- Largely due to industrial producers

Regulated by the South Coast Air Quality Management District (SCAQMD).

Los Angeles, 1975. No filter.

Chevron Refinery, El Segundo. Largest oil refinery on the West Coast (270,000 barrels / day).

1989. Meeting of the South Coast Air Quality Management District and Southern California Association of Governments (Herald-Examiner Collection/Los Angeles Public Library).

The REgional CLean Air Incentives Market (RECLAIM)

Timeline:

- **1989**. The Air Quality Management District introduces aggressive rules and standards (command-and-control)
- Much wailing and gnashing of teeth from industry lobbyists
- **1990**. Congress passes the updated Clean Air Act, in particular requiring significant reductions in NO_x concentrations by 2010
- Congress requires that LA use a **market-based approach** to meet the new standard
  - "historic opportunity to reconcile the nation's economic and environmental aspirations" (US EPA 1992)
- **1994**. RECLAIM is introduced.

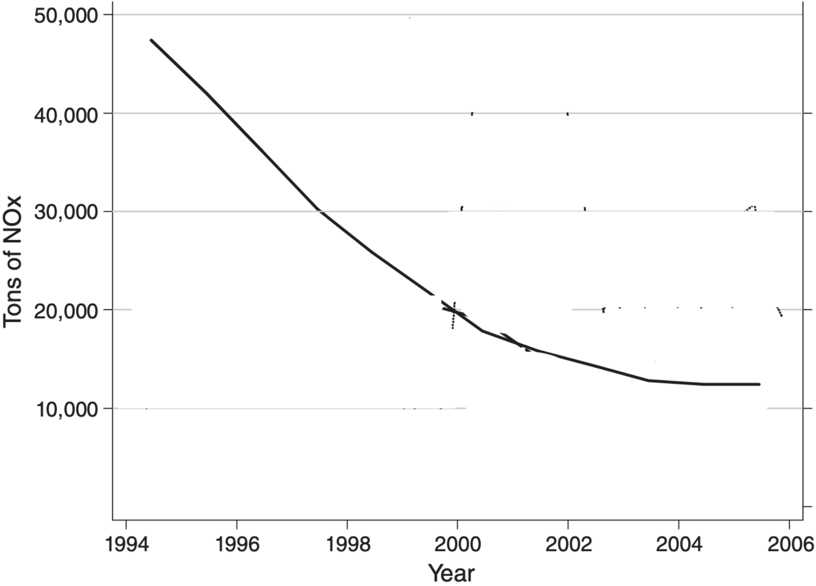
Design of RECLAIM

Design:

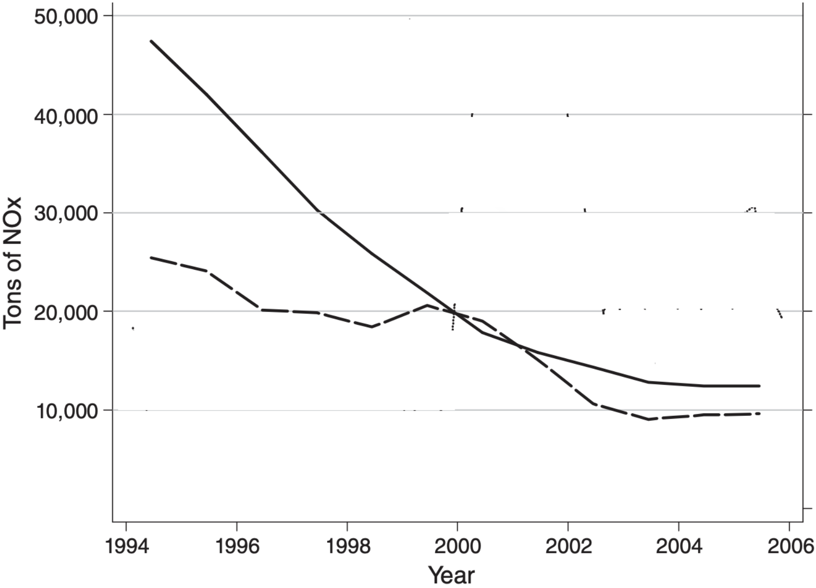
- Includes 392 biggest facilities (emitting $\geq$ 4 tons; 65% of NO_x)
- The small sources ($<$ 4 tons) remained subject to command-and-control
- A RECLAIM credit gives the right to emit one ton of emissions over 12 months
- Credits issued to each facility based on historical fuel use and technology
  - goal was to reduce overall emissions by 70% in 2003
  - achieve by reducing the total NO_x credits issued by 8.3%/year

$\hookrightarrow$

Aggregate distribution of credits over time



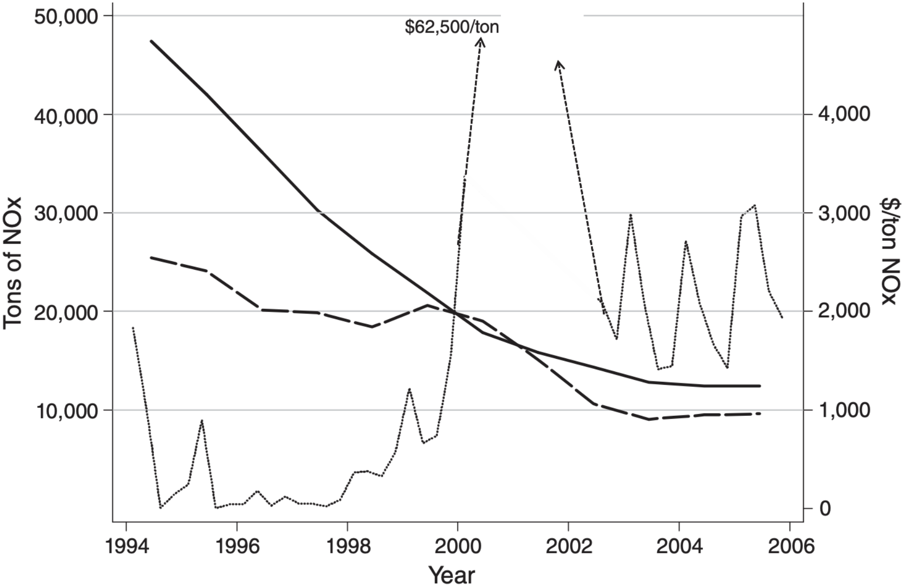
Actual emissions and distribution of credits



Design of RECLAIM, cont'd

- Facilities can **trade** credits with one another each year
  - except: cannot trade from downwind to upwind sources!
- We call this a **cap-and-trade** policy!
- Very generous allocation at the start; led to very low prices
- Major spike in March 2001 ($62,500/ton), coinciding with the California electricity crisis
  - amended rules in May 2001 to exempt 14 power producers and instead subject them to $15,000/ton fees and install best-available technologies
  - brought back into the market in 2007
- More stringent rules in 2004; ↓ 20% over 2007–11

Emission credit prices



Economic evaluation

We will now discuss an economic study that evaluated the performance of this mechanism.

- Meredith Fowlie, Stephen Holland, and Erin Mansur (2012). "What do emissions markets deliver and to whom? Evidence from Southern California's NO_x trading program," American Economic Review, vol. 102 no. 2, pp. 965–993.

Research question: how did RECLAIM affect facilities' emissions (relative to what they would have been under command-and-control)?

Two aspects: (a) did we attain environmental objectives; (b) what were the distributional outcomes across communities?

Econometric issue

Key challenge: construct a credible estimate of emissions we would have observed without RECLAIM

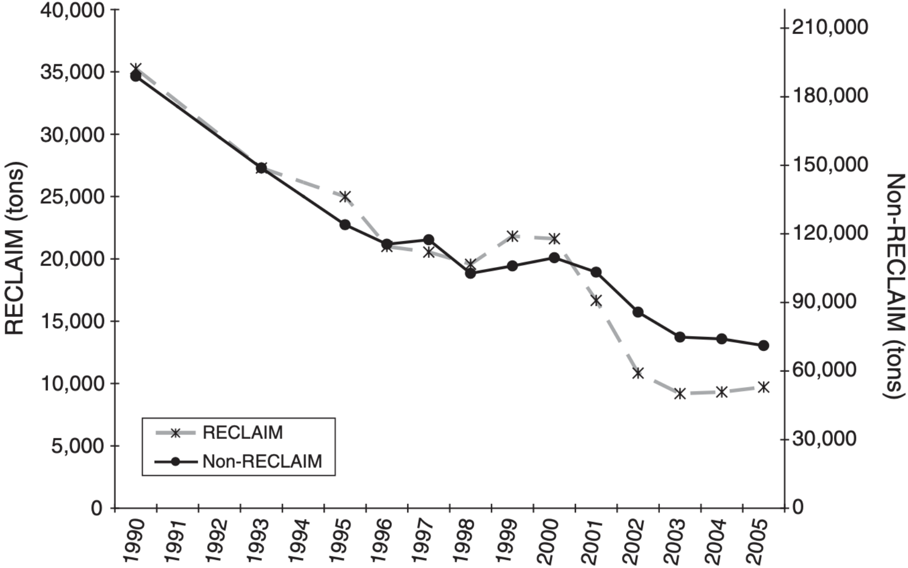
Solution: construct a control group from facilities that are similar to those in RECLAIM, but instead subject to the command-and-control rules

- e.g., large facilities outside of the LA air basin (not subject to SCAQMD jurisdiction)
- smaller facilities, inside of the LA air basin

If we can control for all confounding differences, then

- we can compare the outcomes for RECLAIM facilities ("treatment") with non-RECLAIM facilities ("control")
- gives the causal effect of RECLAIM (versus command-and-control)

RECLAIM v. non-RECLAIM



Constructing the control group

Industry	RECLAIM share	Obs	Mean
Petroleum refining	37.5%	10	880
Electric services	23.9%	21	378
Crude petroleum/natural gas	7.1%	10	116
Cement	4.1%	2	699
Glass containers	3.8%	1	611
Natural gas trans. and distribution	2.3%	8	85
Paper mills	1.8%	6	82
Electric and other services combined	1.6%	4	107
Industrial inorganic chemicals	0.9%	5	31
Steel works, blast furnaces	0.9%	3	103
Steam and air-conditioning supply	0.9%	7	39
Products of petroleum and coal, NEC	0.8%	1	260

Constructing the control group

Table 1—Summary Statistics of NO_x Emissions

Period	RECLAIM	Control
Period 1 (1990–1993)	101.8 (304.4)	102.8 (430.5)
Period 2 (1997–1998)	62.7 (179.8)	80.0 (371.0)
Period 3 (2001–2002)	43.8 (125.4)	67.9 (339.6)
Period 4 (2004–2005)	30.8 (117.1)	53.0 (290.8)

Main comparison: average q_i^{FB} versus average $\overline{q}$

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Main result

Table 7—Environmental Justice Results

	(1)	(2)	(3)	(4)	(5)
Panel A. Change in NO_x emissions between periods 1 and 4					
Treatment	–20.64**				
	(7.81)				
Treat × Period 1 NO_x	–0.19				
	(0.11)				
Treat × income					
Treat × %Minority					
Period 1 NO_x	–0.48***				
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Income					
%Minority					
R^2	0.87				

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Differences across neighborhoods

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Panel A. Change in NO_x emissions between periods 1 and 4					
Treatment	−20.64**	−20.38*	−17.49**	−20.46**	−18.52**
	(7.81)	(8.85)	(6.17)	(7.41)	(7.04)
Treat × Period 1 NO_x	−0.19			−0.19	−0.19
	(0.11)			(0.11)	(0.11)
Treat × income		−1.27		−0.65	
		(0.96)		(1.09)	
Treat × %Minority			0.94		0.43
			(0.60)		(0.36)
Period 1 NO_x	−0.48***	−0.49**	−0.49**	−0.48***	−0.48***
	(0.11)	(0.15)	(0.15)	(0.11)	(0.11)
Income		0.10		0.16	
		(0.80)		(0.74)	
%Minority			−0.35		−0.22
			(0.31)		(0.26)
R^2	0.87	0.85	0.85	0.87	0.87

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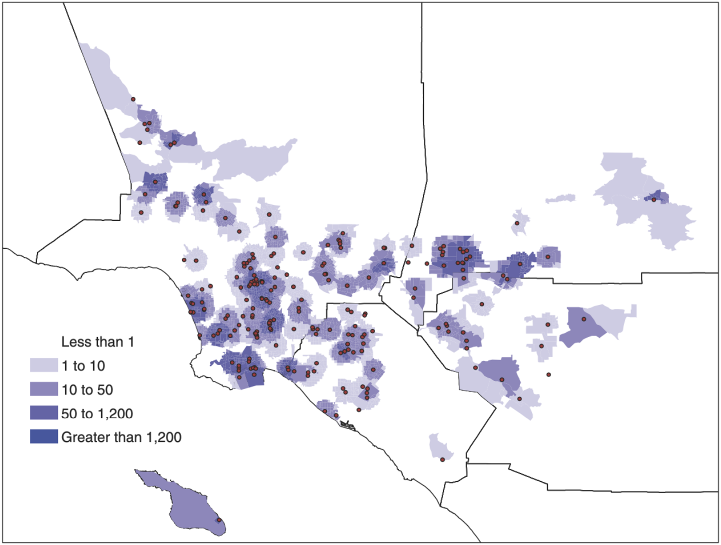
R^2	0.87	0.85	0.85	0.87	0.87

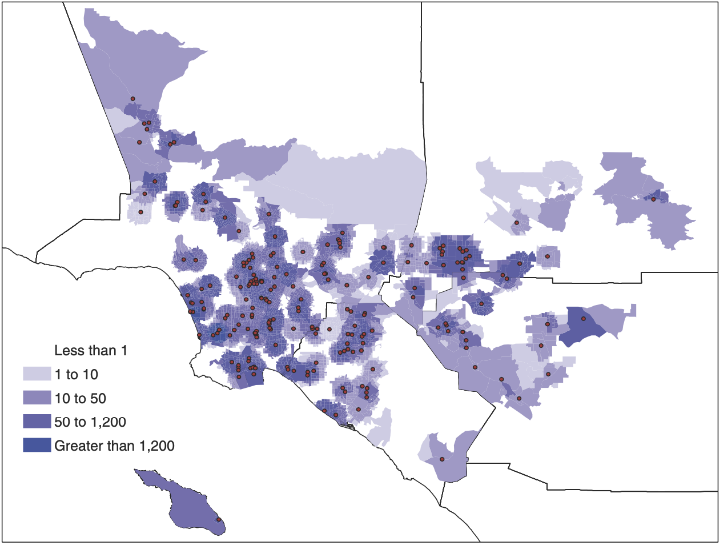
Distribution of outcomes **with** the market

Panel A. Actual emissions under RECLAIM



Distribution of outcomes **without** the market

Panel B. Counterfactual emissions under command-and-control (CAC)



Some places did see higher emissions

Fowlie, Holland, and Mansur (n46, p. 990):

> *The small subset of block groups that are exposed to higher emissions levels under the RECLAIM regime as compared to the CAC counterfactual comprises fewer minority and low income households as compared to the average block. Overall, these households are 34 percent white (versus an average of 30 percent); average household income is $52,000 versus the average $47,000.*

Takeaways

Summarizing, Fowlie, Holland, and Mansur (2012) find:

- **aggregate environmental outcomes** — emissions fell 20% relative to control facilities
- **distributional outcomes** — no statistically significant difference between pollution reductions across neighborhoods with different socioeconomic characteristics

Health outcomes

Gauderman et al. (2015), "Association of improved air quality with lung development in children," New England Journal of Medicine, vol. 372, pp. 905–913.

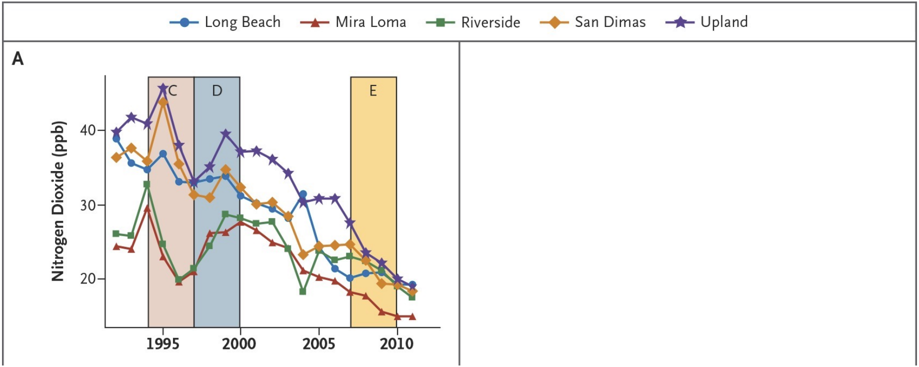
Elementary school students recruited in three cohorts:

- 1992–1994
- 1995–1996
- 2002–2003

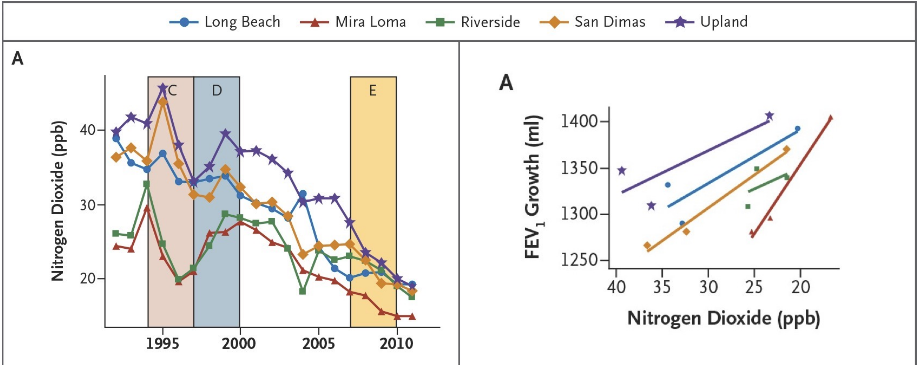
$N = 669 + 588 + 863 = 2120$ children.

Outcome: lung capacity ("forced expiratory volume," FEV)

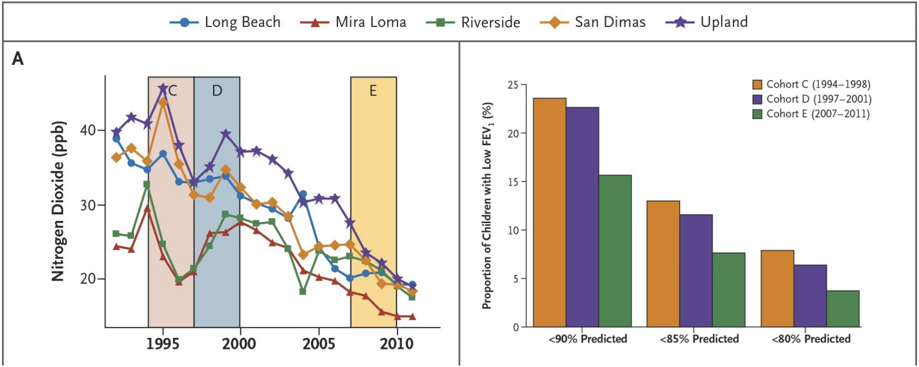
Air pollution for each cohort



Correlation with lung health



Lower pollution, healthier children



Next week

Problem set 2 due tomorrow (5 PST).

Next Monday, we will discuss environmental offsets.

Wednesday (Nov 12): Midterm 2.