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14.03/003 Microeconomic Theory & Public Policy Fall 2024

Lecture slides 18: Externalities part II – Pricing, traffic congestion, and pollution permits

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Four perspectives on externalities

1. Property rights perspective: The Coase Theorem
2. **Collective choice externalities**
3. **Classic pricing problem**
4. **Empirical applications**
    - Mass transit
    - Regulating pollution

Externalities – Classic pricing problem

Externalities: A simple example

Suppose 400,000 commuters must take one of two routes between home and work

- Commute time bridge: $t_B(n_B) = 30 + n_B/20,000$ minutes
- Commute time tunnel: $t_T(n_T) = 40 + n_T/5,000$ minutes

Externalities: A simple example

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- Commute time bridge: $t_B(n_B) = 30 + n_B/20,000$ minutes
- Commute time tunnel: $t_T(n_T) = 40 + n_T/5,000$ minutes

1. What is the free market equilibrium of this problem—and is it likely to be socially efficient?
2. How would the benevolent social planner (BSP) allocate commuters between these two venues?
3. Lets say that commuters value their time at \$60/hr. Should there be a toll, on which route, and for how much?

1. Free market equilibrium (no intervention)

Suppose 400,000 commuters must take one of two routes between home and work

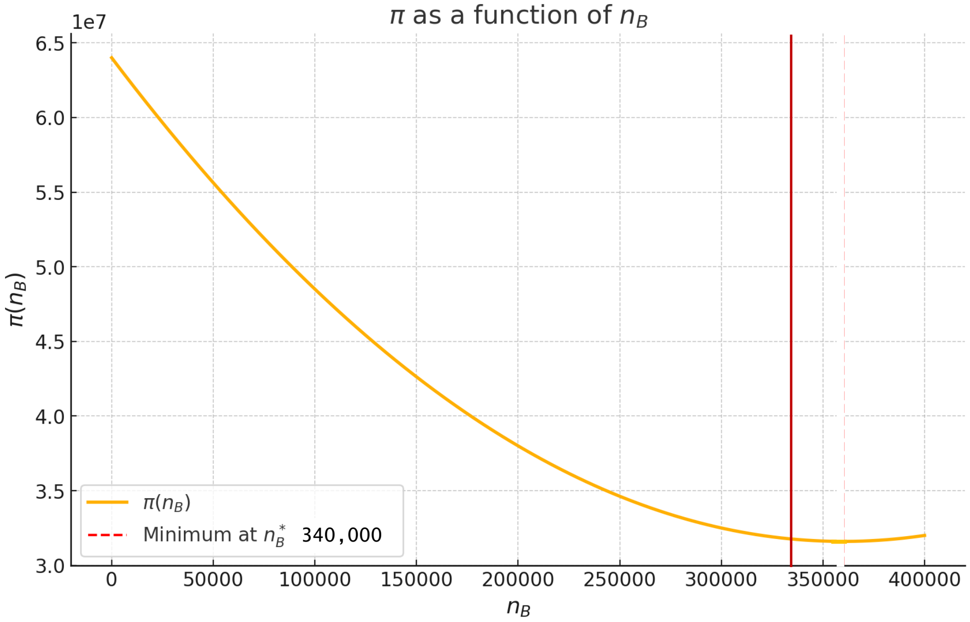
- Commute time bridge: $t_B(n_B) = 30 + n_B/20,000$ minutes
- Commute time tunnel: $t_T(n_T) = 40 + n_T/5,000$ minutes

What is the equilibrium condition that determines the number of commuters on Bridge vs. Tunnel in this setting? (plicker)

1. Free market equilibrium (no intervention)

Suppose 400,000 commuters must take one of two routes between home and work

- Commute time bridge: $t_B(n_B) = 30 + n_B/20,000$ minutes
- Commute time tunnel: $t_T(n_T) = 40 + n_T/5,000$ minutes
- **What is the equilibrium condition that determines the number of commuters on Bridge vs. Tunnel in this setting?**
- **Commuters will choose the fastest route** $\rightarrow$ Arbitrage will equate bridge and tunnel commute times
- In eq'm, consumers must be indifferent between bridge and tunnel
- *Is this likely to be socially efficient?*



π as a function of n_B
1e7
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
$\pi(n_B)$
0
50000
100000
150000
200000
250000
300000
350000
400000
n_B
$\pi(n_B)$
Minimum at n_B^* 340,000

3. Should BSP impose a toll?

– Suppose commuters value their time at $\$60/hour$ ($\$1/min$). A toll can be charged on the bridge or tunnel, what toll implements the (socially optimal) outcome?

From `http://www.wsdot.wa.gov/Tolling/520/520tollrates.htm`
Seattle's SR 520 toll rates for cars and motorbikes (as of Nov 2020):

Monday - Friday	Good To Go! Pass	Pay By Mail
Midnight to 5 a.m.	$1.25	$3.25
5 a.m. to 6 a.m.	$2.00	$4.00
6 a.m. to 7 a.m.	$3.40	$5.40
7 a.m. to 9 a.m.	$4.30	$6.30
9 a.m. to 10 a.m.	$3.40	$5.40
10 a.m. to 2 p.m.	$2.70	$4.70
2 p.m. to 3 p.m.	$3.40	$5.40
3 p.m. to 6 p.m.	$4.30	$6.30
6 p.m. to 7 p.m.	$3.40	$5.40
7 p.m. to 9 p.m.	$2.70	$4.70
9 p.m. to 11 p.m.	$2.00	$4.00
11 p.m. to midnight	$1.25	$3.25

Measuring externalities from mass transit

Anderson, 2014 *AER*

Mass transit is expensive

- Mass transit attracts a disproportionate share of public funds but carries a negligible fraction of commuters
- In Washington, DC—which, until recently, had the second-busiest metro system in the United States—transit accounts for only 5 percent of passenger miles traveled
- In 2010, public transit received 23% of federal highway and transit outlays but accounted for 1% percent of passenger miles traveled
- In 2010, state, local, and federal subsidies exceed $\$40$ billion per year and covered $63\%$of operating costs and 100% of capital costs

Measuring the external benefits of public transit by studying a public transit strike

- October 2003 strike by Los Angeles County Metropolitan Transportation Authority (MTA) workers income commuters
- Strike lasted 35 days and shut down MTA bus and rail lines. Using hourly data on traffic speeds for all major Los Angeles freeways
- Study effects on congestion on highways that public transit users would *counterfactually* have taken
- Research design: Regression Discontinuity (RD) in date of strike start/stop
- **Question: How do we know what highways transit riders would counterfactually have taken?**

Los Angeles major public transit routes and freeways

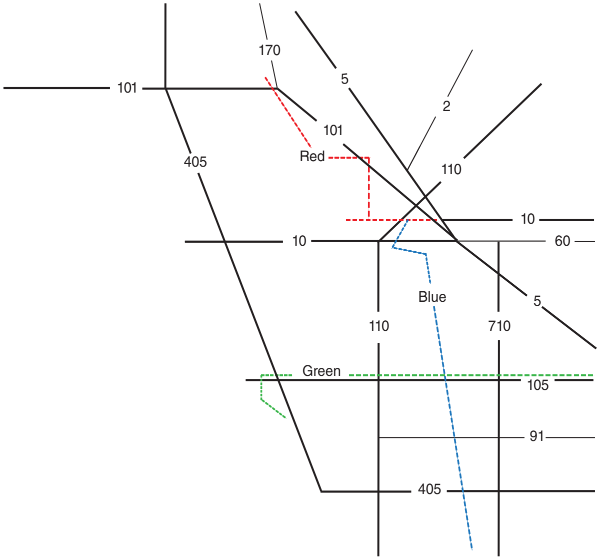


Figure 1. Los Angeles Freeways and Rail Lines, 2003

Which highways would transit riders have counterfactually driven?

- One theory: They are evenly distributed across roadways
- Alternative theories?
- *Perhaps people ride mass transit to avoid driving on the most congested roads!*
- **From an externalities perspective, does it matter?**

Key Regression Discontinuity evidence

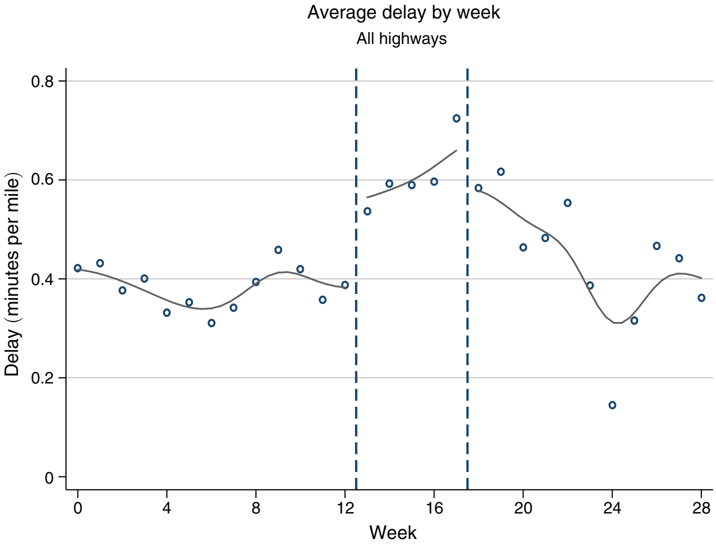


Figure 2. Weekly Peak Hour Delay on Major Los Angeles Freeways, 7/14/2003 to 1/30/2004

Results for major freeways

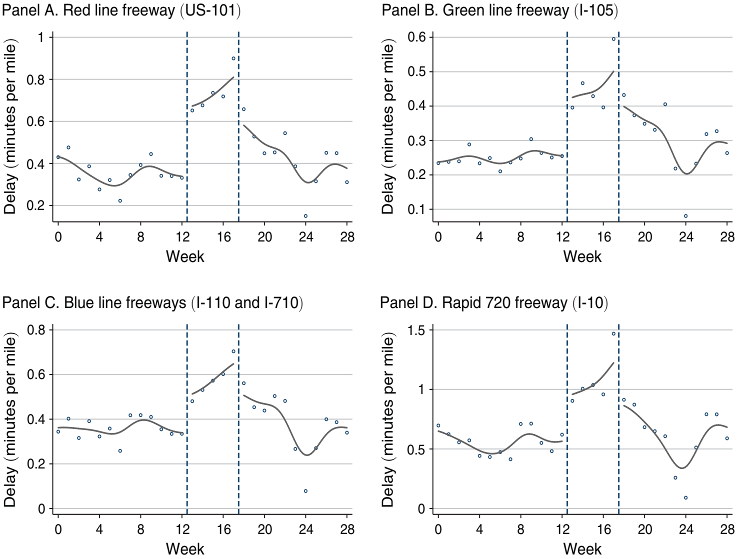


Figure 3. Average Weekly Peak Hour Delay on Specific Los Angeles Freeways, 7/14/2003 to 1/30/2004

Falsification exercise: Effects on highways not in LA MTA service area

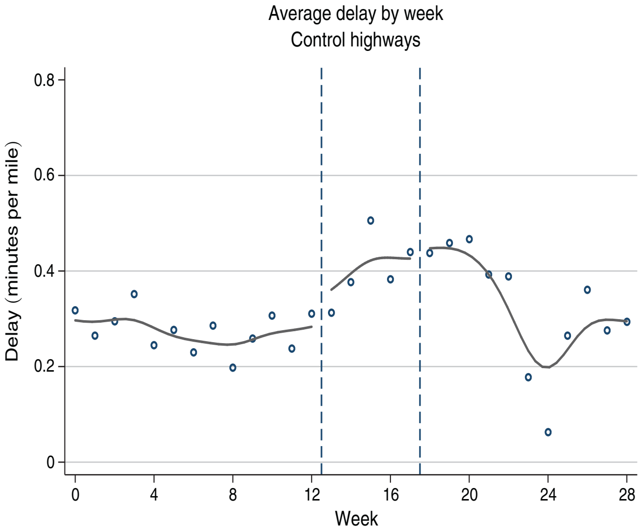


FIGURE 5. WEEKLY PEAK HOUR DELAY ON ORANGE/VENTURA COUNTY FREEWAYS, 7/14/2003 TO 1/30/2004

Delays per minute during peak hours

TABLE 4—EFFECT OF STRIKE ON DELAYS DURING ALL PEAK HOURS

Average delay (in minutes per mile)	(1)	(2)	(3)	(4)	(5)	(6)
Strike	0.194	0.332	0.218	0.190	0.357	0.125
	(0.041)	(0.076)	(0.052)	(0.051)	(0.128)	(0.042)
Date	−0.004	−0.003	−0.002	−0.003	−0.005	−0.005
	(0.002)	(0.003)	(0.002)	(0.002)	(0.004)	(0.002)
Date × strike	0.007	0.006	−0.001	0.007	0.012	0.007
	(0.002)	(0.003)	(0.002)	(0.003)	(0.007)	(0.002)
Average delay prestrike	0.409	0.369	0.264	0.357	0.600	0.434
Freeways	All	101	105	110 and 710	10	Other
Parallel transit line		Red line	Green line	Blue line	Rapid 720	
Sample size	178,549	15,854	31,058	19,152	15,357	97,128

Notes: Each column represents a separate VMT-weighted regression, with weights equal to (length of highway covered by detector i) × (average prestrike traffic flow over detector i). The observation is the detector-hour, and the sample is limited to weekdays from 7–10 AM and 2–8 PM within 28 days of the strike's beginning. Parentheses contain clustered standard errors that are robust to within-day and within-detector serial correlation. All regressions include day-of-week and detector fixed effects.

Delays per minute during peak morning hours

TABLE 5—EFFECT OF STRIKE ON DELAYS DURING PEAK MORNING HOURS

Average delay (in minutes per mile)	(1)	(2)	(3)	(4)	(5)	(6)
Strike	0.314	0.482	0.283	0.189	0.619	0.258
	(0.075)	(0.148)	(0.090)	(0.073)	(0.179)	(0.079)
Date	−0.003	−0.003	0.003	−0.002	−0.013	−0.003
	(0.003)	(0.005)	(0.002)	(0.004)	(0.009)	(0.004)
Date × strike	0.000	−0.005	−0.012	0.008	0.010	0.001
	(0.005)	(0.007)	(0.004)	(0.006)	(0.012)	(0.005)
Average delay prestrike	0.472	0.392	0.268	0.485	0.953	0.464
Freeways	All	101	105	110 and 710	10	Other
Parallel transit line		Red line	Green line	Blue line	Rapid 720	
Sample size	58,380	5,210	10,136	6,214	5,074	31,746

Notes: Each column represents a separate VMT-weighted regression, with weights equal to (length of highway covered by detector i) × (average prestrike traffic flow over detector i). The observation is the detector-hour, and the sample is limited to weekdays from 7–10 AM within 28 days of the strike's beginning. Parentheses contain clustered standard errors that are robust to within-day and within-detector serial correlation. All regressions include day-of-week and detector fixed effects.

Delays per minute during peak evening hours

TABLE 6—EFFECT OF STRIKE ON DELAYS DURING PEAK AFTERNOON HOURS

Average delay (in minutes per mile)	(1)	(2)	(3)	(4)	(5)	(6)
Strike	0.157	0.266	0.213	0.197	0.279	0.085
	(0.040)	(0.064)	(0.061)	(0.056)	(0.132)	(0.049)
Date	−0.005	−0.004	−0.005	−0.004	−0.004	−0.006
	(0.002)	(0.003)	(0.002)	(0.002)	(0.005)	(0.002)
Date × strike	0.010	0.011	0.005	0.007	0.017	0.011
	(0.002)	(0.004)	(0.002)	(0.002)	(0.008)	(0.002)
Average delay prestrike	0.384	0.361	0.274	0.300	0.401	0.431
Freeways	All	101	105	110 and 710	10	Other
Parallel transit line		Red line	Green line	Blue line	Rapid 720	
Sample size	120,007	10,575	20,922	12,938	10,283	65,289

Notes: Each column represents a separate VMT-weighted regression, with weights equal to (length of highway covered by detector i) × (average prestrike traffic flow over detector i). The observation is the detector-hour, and the sample is limited to weekdays from 2–8 PM within 28 days of the strike's beginning. Parentheses contain clustered standard errors that are robust to within-day and within-detector serial correlation. All regressions include day-of-week and detector fixed effects.

Effects on road occupancy—vehicle directly over sensor

TABLE 7—EFFECT OF STRIKE ON FREEWAY OCCUPANCY

Average share of time detector is occcupied	(1)	(2)	(3)	(4)	(5)	(6)
Strike	0.013	0.023	0.019	0.016	0.022	0.008
	(0.003)	(0.006)	(0.004)	(0.004)	(0.009)	(0.003)
Date	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Date × strike	0.000	0.000	0.000	0.000	0.001	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Average share of time detector is occupied prestrike	0.112	0.121	0.097	0.115	0.129	0.110
Freeways	All	101	105	110 and 710	10	Other
Parallel transit line		Red line	Green line	Blue line	Rapid 720	
Sample size	179,680	16,222	31,112	19,152	15,668	97,526

Notes: Each column represents a separate VMT-weighted regression, with weights equal to (length of highway covered by detector i) × (lanes at detector i). The observation is the detector-hour, and the sample is limited to weekdays from 7–10 AM and 2–8 PM within 28 days of the strike's beginning. Parentheses contain clustered standard errors that are robust to within-day and within-detector serial correlation. All regressions include day-of-week and detector fixed effects.

Effects on traffic flow—throughput of roadways

TABLE 8—EFFECT OF STRIKE ON TRAFFIC FLOWS

Hourly traffic flow per lane	(1)	(2)	(3)	(4)	(5)	(6)
Strike	−31.3	−68.2	−9.4	−1.4	−61.1	−29.4
	(9.7)	(17.3)	(11.7)	(18.1)	(19.6)	(9.0)
Date	0.81	0.79	0.91	0.46	1.14	0.83
	(0.40)	(0.58)	(0.62)	(0.94)	(0.88)	(0.33)
Date × strike	−1.85	−2.50	−1.29	−2.46	−2.45	−1.53
	(0.61)	(0.85)	(0.73)	(1.07)	(1.06)	(0.60)
Average hourly flow prestrike	1,399	1,576	1,349	1,403	1,455	1,353
Freeways	All	101	105	110 and 710	10	Other
Parallel transit line		Red line	Green line	Blue line	Rapid 720	
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Traffic time-shifting in response to delays

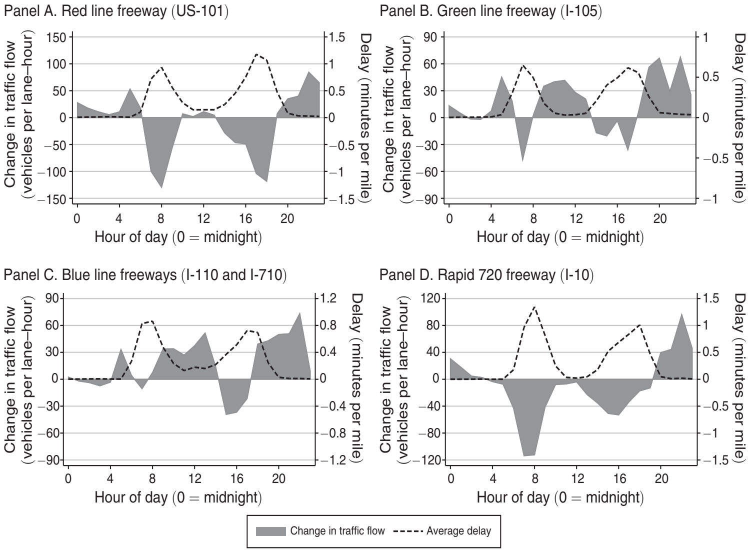


FIGURE 4. CHANGES IN TRAFFIC FLOWS BY HOUR OF DAY ON SPECIFIC LOS ANGELES FREEWAYS

A tiny fraction of commuters use public transmit: Is it worth the cost?

Benefits in dollars

- An increase of 0.19 minutes per mile in traffic delays in Los Angeles implies an aggregate increase of 114 **million hours of delay per year**
- Conservatively assumes that transit has no effect on arterial road congestion
- Valuing commuter time at half the average hourly wage ($\$10.30$), an annual congestion relief benefit from Public transit of $\$1.2$ billion per year (in $2014\$$)
- Motorists **hate** driving in traffic. Using delay multiplier of 1.8, benefit is $\$2.1$ billion

Benefits per public transmit Passenger Mile (PM)

- LA MTA carried approximately 1 billion PM during peak hours in 2003
- Congestion relief benefit per peak-hour transit PM is $\$1.20$ – $\$2.16$ per PM

Cost-benefit analysis of public transit investments

TABLE 11—CAPITAL INVESTMENT BENEFITS

	Baseline	Low ridership growth	High bus ridership	"Extreme" VMT elasticity
Fixed parameters				
2001 ridership (Red, Green, Blue lines)	69 million	—	—	—
2010 ridership (Red, Green, Blue lines)	85 million	—	—	—
Share of ridership that is peak hour	57 percent	—	—	—
2010 rail operating subsidy ($2003)	$115 million	—	—	—
Annual real wage growth	1 percent	—	—	—
Real discount rate	5 percent	—	—	—
Short-run congestion relief benefit per peak mile	$2.50	—	—	—
Varying parameters				
Annual ridership growth (to max of 175 million)	1.7 million	0.9 million	—	—
Share riders retained if replacing rail with bus	26 percent	—	50 percent	—
2010 operating subsidy if replacing rail with bus	$126 million	—	$215 million	—
VMT elasticity w.r.t. total travel costs	−1.5	—	—	−2.0
Long-run congestion relief benefit per peak mile	$1.61	—	—	$1.50
Total costs and benefits				
Capital cost of rail system	$7.1 billion	$7.1 billion	$7.1 billion	$7.1 billion
Present value of gross benefits	$13.7 billion	$11.8 billion	$12.3 billion	$12.7 billion
Present value of net benefits	$6.6 billion	$4.8 billion	$5.2 billion	$5.7 billion

Notes: Cell entry of "—" indicates cell contains same value as baseline column. All dollar figures are expressed in 2003 US$ for comparability. Ridership figures and operating subsidies come from LACMTA reports. Real wage growth comes from BLS (2006), and real discount rate comes from US Department of Transportation (2003).

The U.S. Sulfur Dioxide Cap and Trade Program

Coal deposits in the United States

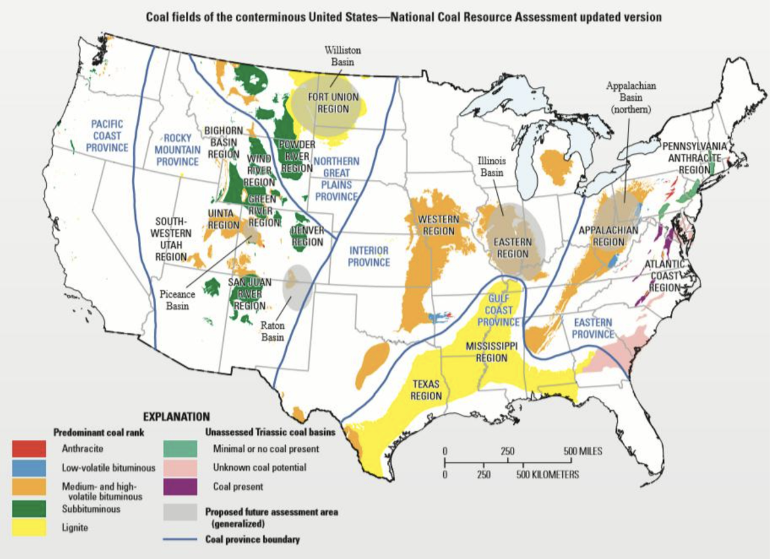
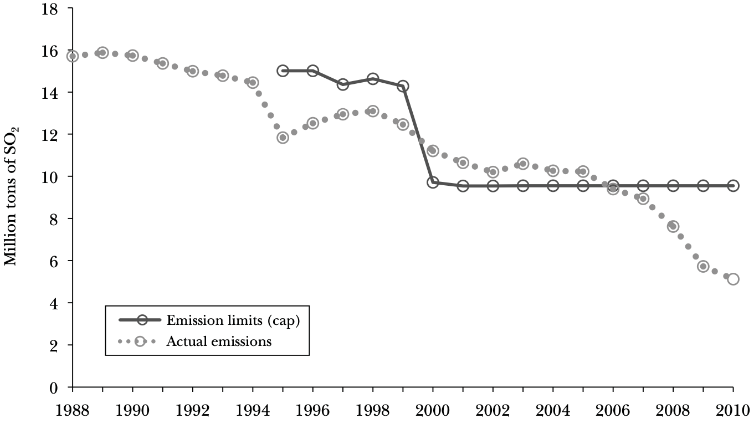


Figure 1. Coal fields of the conterminous United States from the National Coal Resource Assessment updated version (modified from East, 2013).

SO_2 quotas and output, 1988 – 2010

Figure 1
SO_2 Caps and Emissions, 1988–2010



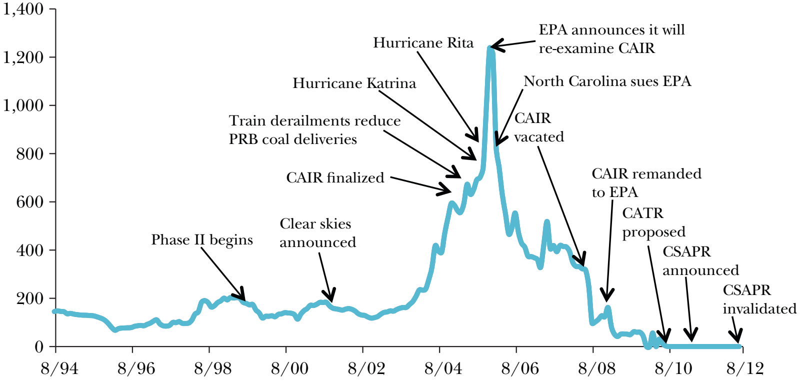
Source: Ellerman (2003); US Environmental Protection Agency (2012).
Notes: The emission limits shown for the period 1995–1999 are equal to the Phase 1 units' cap plus Phase 2 units' emissions. Actual emissions shown for all years are the sum of emissions from Phase 1 and Phase 2 units.

Regulatory history and SO_2 permit pricing

Figure 2

SO_2 Allowance Prices and the Regulatory Environment, 1994–2012

(1995 dollars per ton)



Source: Data on spot prices compiled by Power & Energy Analytic Resources (PEAR) Inc. from Cantor Fitzgerald until September 11, 2001, and from ICAP United thereafter.
Notes: CAIR is "Clean Air Interstate Rule." CATR is "Clean Air Transport Rule." CSAPR is "Cross-State Air Pollution Rule."

Oh, the ironies

1. The goal of reducing SO_2 emissions was met and exceeded
   - But ecological benefits have been relatively minor because it takes much longer than thought to reverse the acidification of ecosystems
2. The completely unanticipated benefits of the program have been massive
   - More than 95% of benefits are associated with human health impacts of reduced levels of airborne fine sulfate particles less than 2.5 micrometers in diameter

Estimated benefits of SO_2 reductions

Estimated Annual US Benefits and Costs of the SO_2 Allowance Trading Program; Title IV, Clean Air Amendments of 1990
(billions of US 2000 Dollars)

Benefits	
Mortality	50–100
Morbidity	3–7
Recreational visibility	2–3
Residential visibility	2–3
Ecosystem effects	0.5
Total	**59–116**
Costs	**0.5–2.0**
Net benefits	**58–114**

Source: Burtraw, Krupnick, Mansur, Austin, and Farrell (1998); Burtraw (1999); Chestnut and Mills (2005); Banzhaf, Burtraw, Evans, and Krupnick (2006).

Oh, the ironies

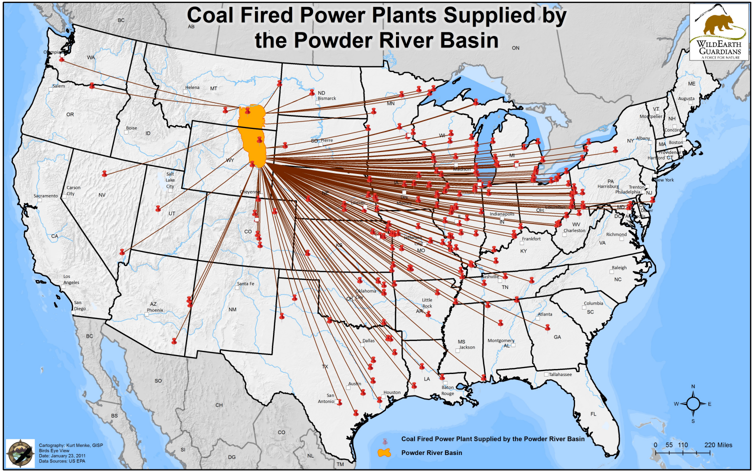
1. The goal of reducing SO_2 emissions was met and exceeded
2. The completely unanticipated benefits of the program have been massive
3. Realized costs of the SO_2 allowance trading program were *substantially less* than forecast
   - The cause was *railroad deregulation*
   - Cost of bringing sub-bituminous coal from the Powder River Basin to centers of high demand east of the Mississippi River fell dramatically
   - Much of that cost reduction was due to *railroad deregulation*

Sub-bituminous coal

Sub-bituminous coals, in the United States, typically have a sulfur content less than 1% by weight, which makes them an attractive choice for power plants to reduce SO_2 emissions under the Acid Rain Program.

Sub-bituminous coals release large quantities of greenhouse gases when burned, compared to higher grades of coal.[3]

The Powder River Basin



Oh, the ironies

1. The goal of reducing SO_2 emissions was met and exceeded
2. The completely unanticipated benefits of the program have been massive
3. Realized costs of the SO_2 allowance trading program were *substantially less* than forecast
4. Sub-bituminous goal is bad news for greenhouse gas emissions
   - It's particularly high in C – releases more CO_2 when burned than higher grades of coal
   - This concern was barely on the radar in 1990
5. Cap and trade passed in 1990 with overwhelming bipartisan support — a market-based solution, applauded by economists and conservative policy makers
   - Twenty years later (and continuing to present), 'free market' conservatives reject market-based solutions for addressing pollution and other externalities
   - One major political party generally rejects most environmental and climate science

Conclusions

Summary

Externalities are ubiquitous

- Arise when an economic actor does not face the “correct price” for her actions
- Externalities are not limited to traditional side effects of production and consumption, e.g., pollution, noise, congestion, speeding, carrying a firearm
- Can also occur in social interactions where groups of rational actors ends up at an undesirable equilibrium due to mis-coordination, social spillovers, FOMO
- Law and policy has a crucial role in “internalizing” externalities
- Taxing externalities can potentially *reduce* distortions
- Nevertheless, these remedies are always contentious