Topic 7

- Emission permit trading programs
- Emission permit trading in-class exercise
- Sulfur dioxide permit market

Emission Permit Trading Programs

Selected Trading Programs Operating or Planned, 2011

Program	Status	Item Traded
1990 Clean Air Act	Operating	Tons of SO_2 emissions from power plants
Southern California Reclaim	Operating	Tons of SO_2 and NO_X from large industrial sources
California Trading Program	Planned	Tons of greenhouse gases
New Zealand Trading Program	Operating	Tons of greenhouse gases
Kyoto Protocol Clean Development Mechanism	Operating	Tons of greenhouse gases from projects in developing countries
European Trading Scheme	Operating	Tons of greenhouse gases from large power, industrial, and cement plants
Regional Greenhouse Gas Initiative	Operating	Tons of greenhouse gases from large plants in northeastern U.S. states
Renewable Energy Certificates	Operating	Certificates for each 1,000 kwh of renewable energy produced
Illinois Emission Reduction Market System	Operating	Tons of volatile organic compounds emitted from large sources in eight Illinois counties
China Trading Program	Planned	Tons of CO_2 emissions
Long Island Sound Nitrogen Trading Program	Operating	Pounds of waterborne nitrogen emissions from wastewater treatment plants
Chesapeake Bay Agreement	Planned	Pounds of waterborne nutrients (nitrogen and phosphorus)
San Francisco Bay Offset Program	Planned	Kilograms of waterborne mercury emissions
Ohio Wetlands Mitigation Program	Operating	Acres of restored, enhanced, or preserved wetlands

Source: Field and Field, 6th ed.

Regional Greenhouse Gas Initiative

- RGGI is operating as of Sept. 25, 2008 (www.rggi.org)
  - ▷ Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont
  - ▷ Quarterly auctions (sealed-bid, uniform-price)
  - ▷ September, 2008, market clearing price $3.07 per ton
  - ▷ September, 2020, market clearing price $6.82 per ton

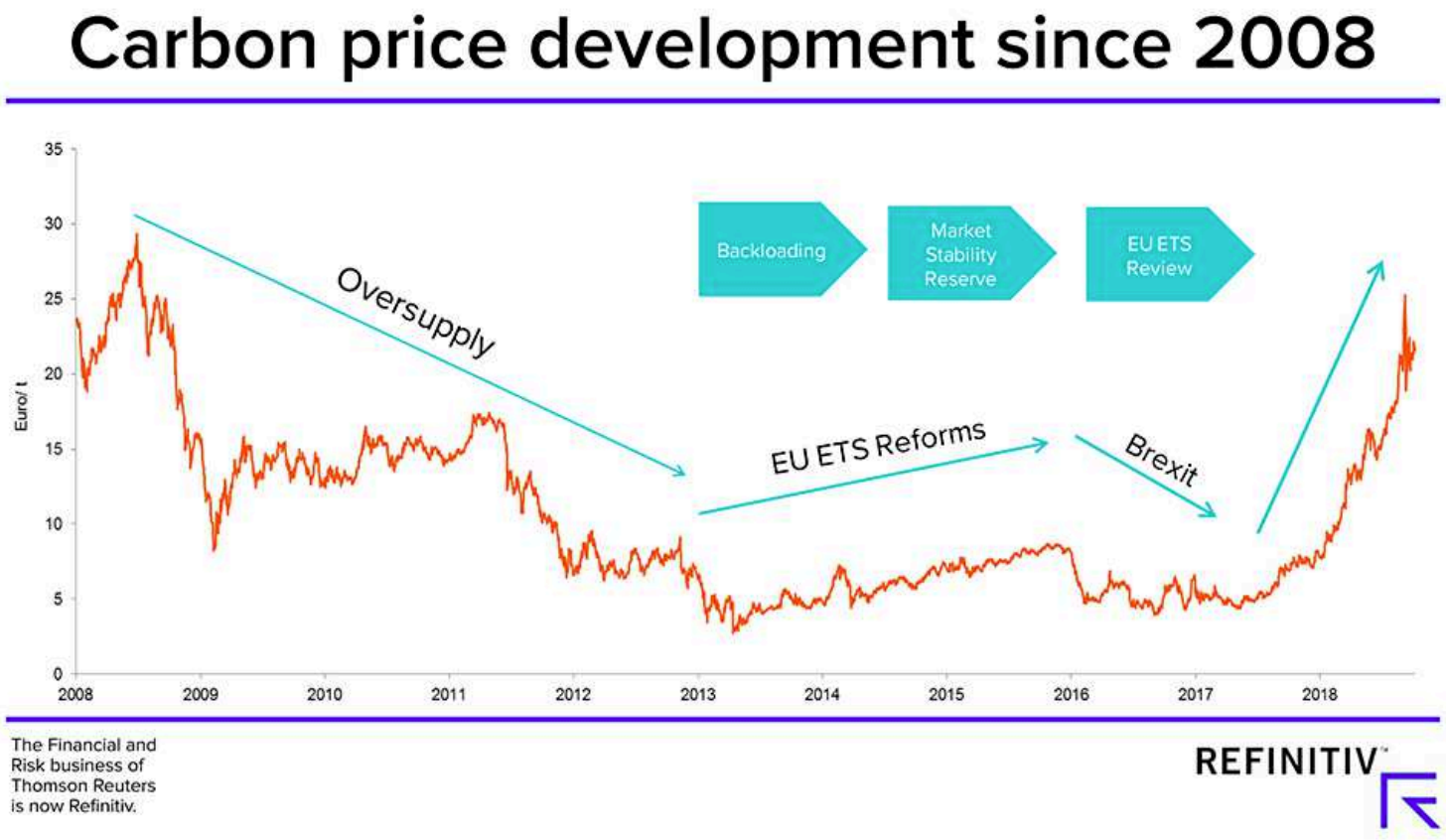
European Union Emission Trading System (EU ETS)

- Covers 10,000+ facilities ($\sim$half of EU's CO_2 emissions)
- Emission permits distributed for free by EU countries
- Spot market price (EUA - Dec 10, 2008) €14.54 ($19.46) per ton (www.cantorco2e.com)

EU ETS Collapse

- Present Garrison slides

EU ETS Rebound



Source: https://www.refinitiv.com/perspectives/market-insights/will-high-european-carbon-prices-last

In-Class Permit Trading Exercise See Homework for date

- **Participants:** Each student will be assigned a number (even number of participants). Each student represents a firm.
- **Output market:** Firms take the market price of 40 as given
- **Production:** $C(Q) = Q$ up to a capacity of 20
- **Pollution:** Each unit of output produces one unit of pollution
- **Pollution abatement:** For odd-numbered firms, the cost of reducing pollution by A units is $C^A_{odd}(A) = 3A^2$. For even-numbered firms, the cost is $C^A_{even}(A) = A^2$. Thus marginal abatement costs are $6A$ for odd-numbered firms and $2A$ for even-numbered firms.
- **Permits:** Each firm is issued 10 permits.

In-Class Permit Trading Exercise

- See course web site for date and details
- Blackboard presentation of solution method
  - ▷ I.e., work Homework 7 in class.
- Blackboard example of filling out trading slip and production report.

Sulfur Dioxide Emissions Permit Trading

- SO_2 emission permit trading in the U.S. since 1995
- Title IV of the 1990 Clean Air Act Amendments
  - ▷ U.S. Acid Rain Program
- Target: Electric utility emissions of SO_2
  - ▷ Mainly coal-fired electric generating plants
  - ▷ 1.7 MW^e plant can put 1100 tons of sulfuric acid in the environment each day
- SO_2 and NO_x react in the atmosphere to form sulfuric and nitric acids (deposited as acid rain)

Phase in of Regulation

- Phase I (1995–1999): 263 dirtiest large generating units required to reduce emissions by about 3.5 million tons of SO_2 per year
- Phase II (2000–): virtually all fossil-fueled electric generating plants subject to a national cap on aggregate annual SO_2 emissions (units exceeding 25 MW^e)
- Caps enforced through annual issuance of tradeable emission allowances (good for 1 ton of SO_2) (recorded in EPA's allowance tracking system)
- Each unit has 30 days after the end of each year to deliver to the EPA allowances sufficient to cover its emissions during the year
- EPA then cancels allowances needed to cover emissions
- Substantial financial penalties for failure to cover emissions
- Can bank for future use, but can't borrow from the future

Trading of Allowances

- Units allocated a certain number of allowances each year (based on baseline emissions using data from 1985–1987)
  - ▷ $\frac{1 \text{ ton}}{2000 \text{ lb}}$ baseline heat input (fuel)
    $\times \min\{1985 \text{ emission rate lb/mmBtu}, 1.2\text{lb/mmBtu}\}$
- Can cover emissions with allocated allowances, buy, sell, or bank
- Hold back 2.8% of allowances for annual auction (proceeds returned pro rata)
- Freely traded

Monitoring

- Utilities required to install continuous emission monitoring system (CEMS) equipment (hourly reporting)
  - ▷ On stack of every affected unit
  - ▷ Initial capital cost $709,000 per unit (1996 dollars)
  - ▷ Annual operating cost $46,780 per unit (1996 dollars)
- Data verified by EPA and made public
- Severe penalties for inaccurate monitoring

Switching and Scrubbing

- Two primary ways to reduce SO_2 emissions

  1. Switch to lower sulfur coal

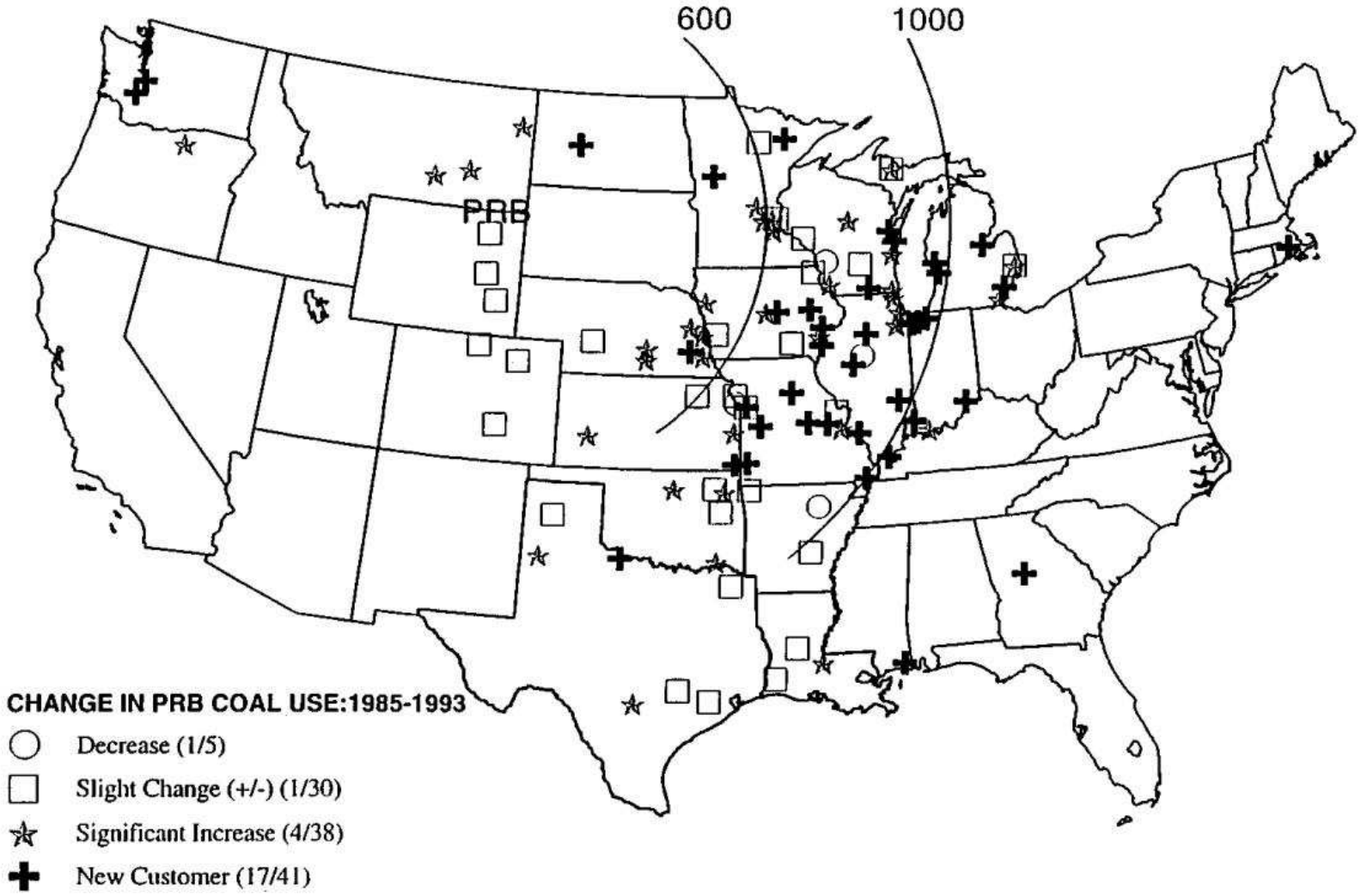
  2. Install and run flue gas desulfurization equipment (scrubbers) Remove 95% of SO_2 by a chemical reaction with limestone

Switching

- Switching choices
  - ▷ Lower sulfur bituminous coal
  - ▷ Powder River Basin subbituminous coal – low Btu, low extraction cost, low sulfur content
  - ▷ Significant costs to covert a generating unit built for bituminous coal for PRB coal
    - ◇ upgrade precipitators and coal and ash-handling equipment

- 1980 deregulation of railroads ended Burlington Northern RR's monopoly over transport out of the PRB
  - ▷ Rail rates fell by half

Changing Incentives for Switching



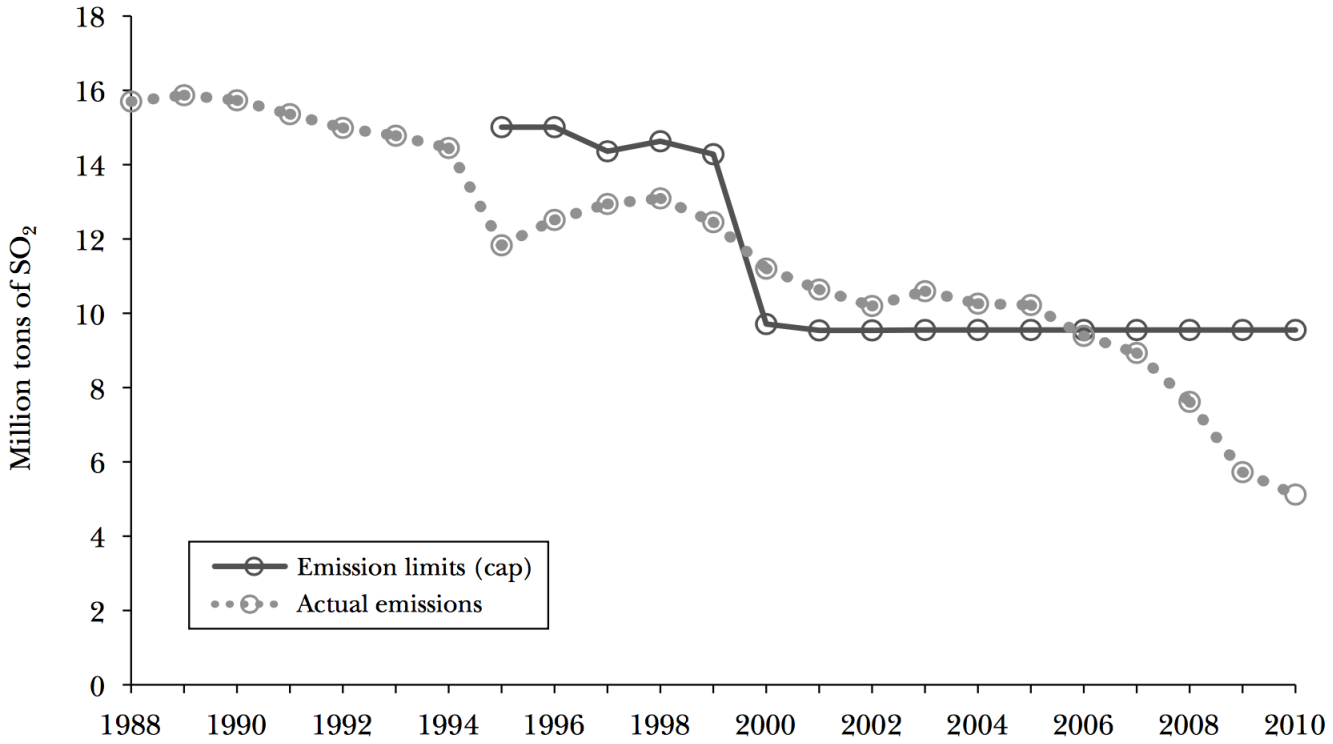
Source: Ellerman and Montero (1998); see also Ellerman et al. (2000), Figure 4.2.

Scrubbing

- Flue gas desulfurization (FGD)
  - ▷ spray an alkaline solution or slurry (typically based on lime or limestone) into the flue gas to react with the SO_3 and SO_2 to form a sulfate or sulfite
  - ▷ limestone and sulphur combine to form either a wet paste or a dry powder.
  - ▷ problems: corrosion, scaling, plugging, and waste disposal
  - ▷ for a base-load plant must install extra FGD capacity to maintain availability of full capacity
- Operating cost of a scrubber includes
  - ▷ limestone, sludge disposal, "parasitic" loss of power to run the scrubber

SO2 Emission Quantities

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.

Marginal Cost of Abatement

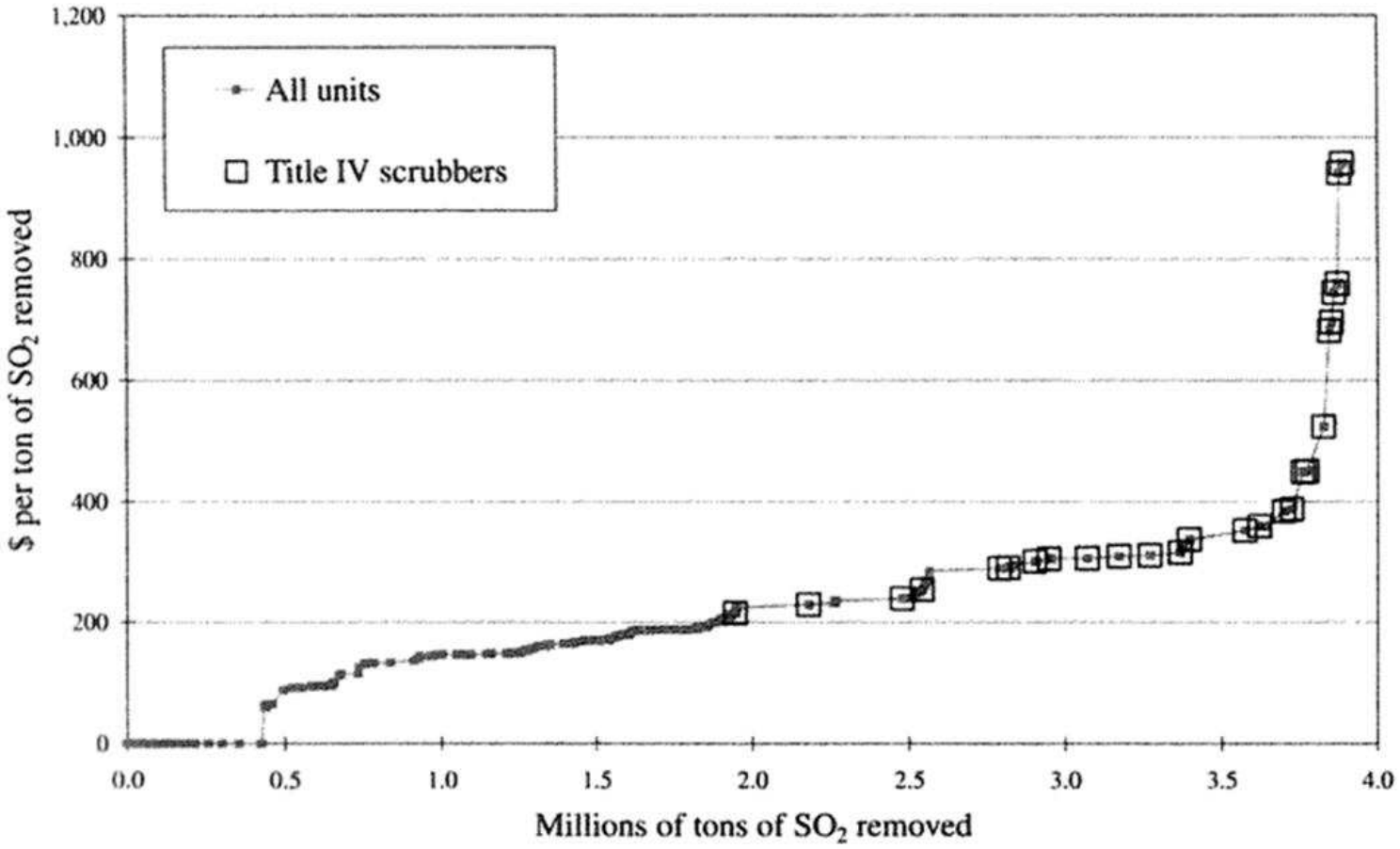
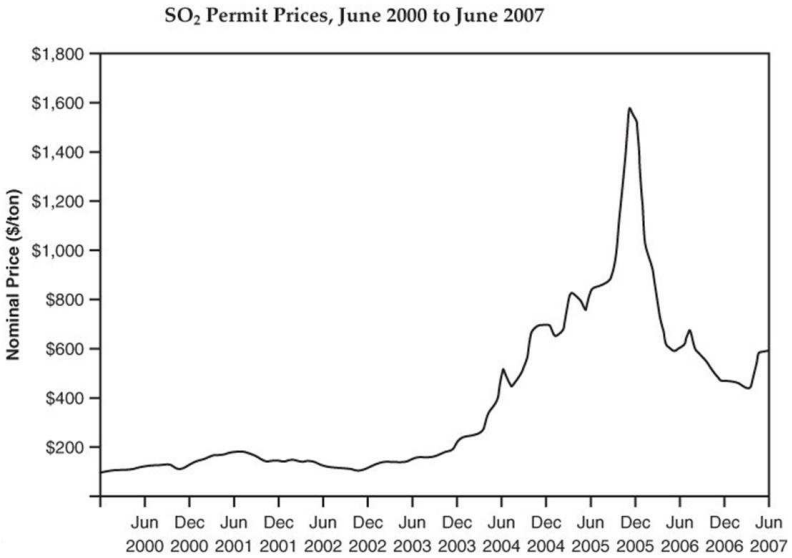
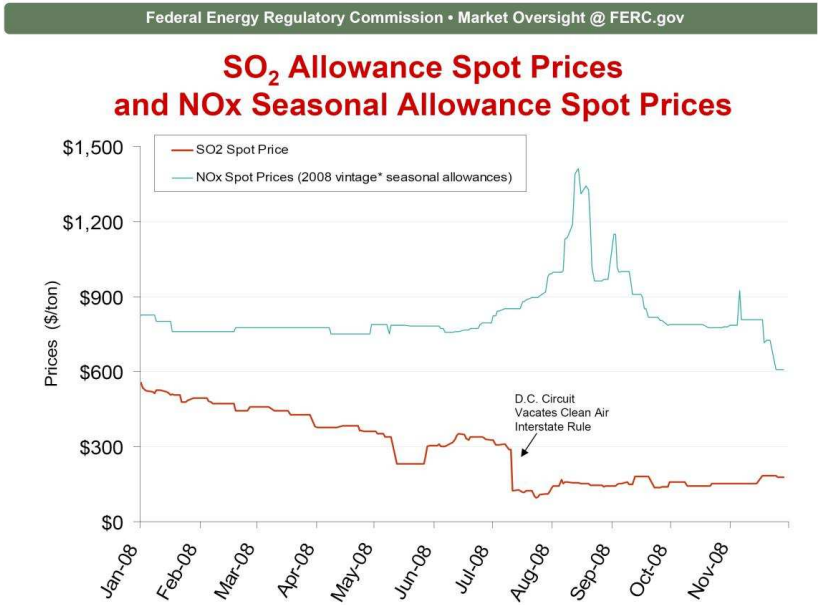


Figure 9.1. Long-run "marginal" cost for Phase I units.

Allowance Trading



Source: U.S. Environmental Protection Agency, *Acid Rain and Related Programs: 2006 Progress Report*, Washington, DC, 2007, p. 46.

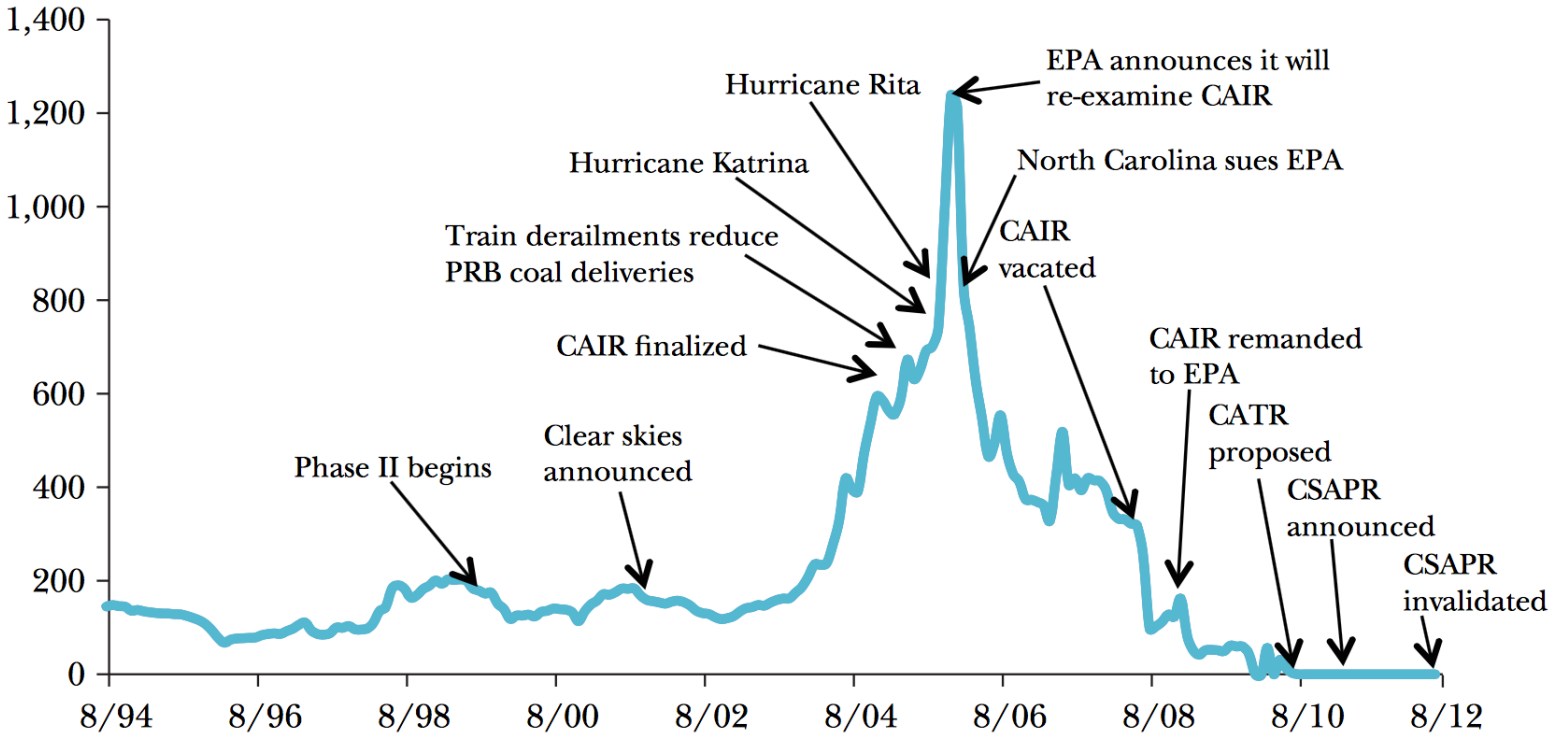


Spot market price (SPOT SO2 - Oct 10, 2008) $140 per ton (Amerex) Price trended downward to near zero by Dec 2011, Field and Field (2013), p.312

SO2 Regulation Events

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."

Equimarginality

- Power plant abatement decision

$$MAC(A) = \text{price of permit}$$

- Marginal abatement cost is the minimum of
  - ▷ marginal cost for lower-sulfur coal (to eliminate one ton of sulfur dioxide)
  - ▷ marginal cost of scrubbing one ton of sulfur dioxide

Equimarginality

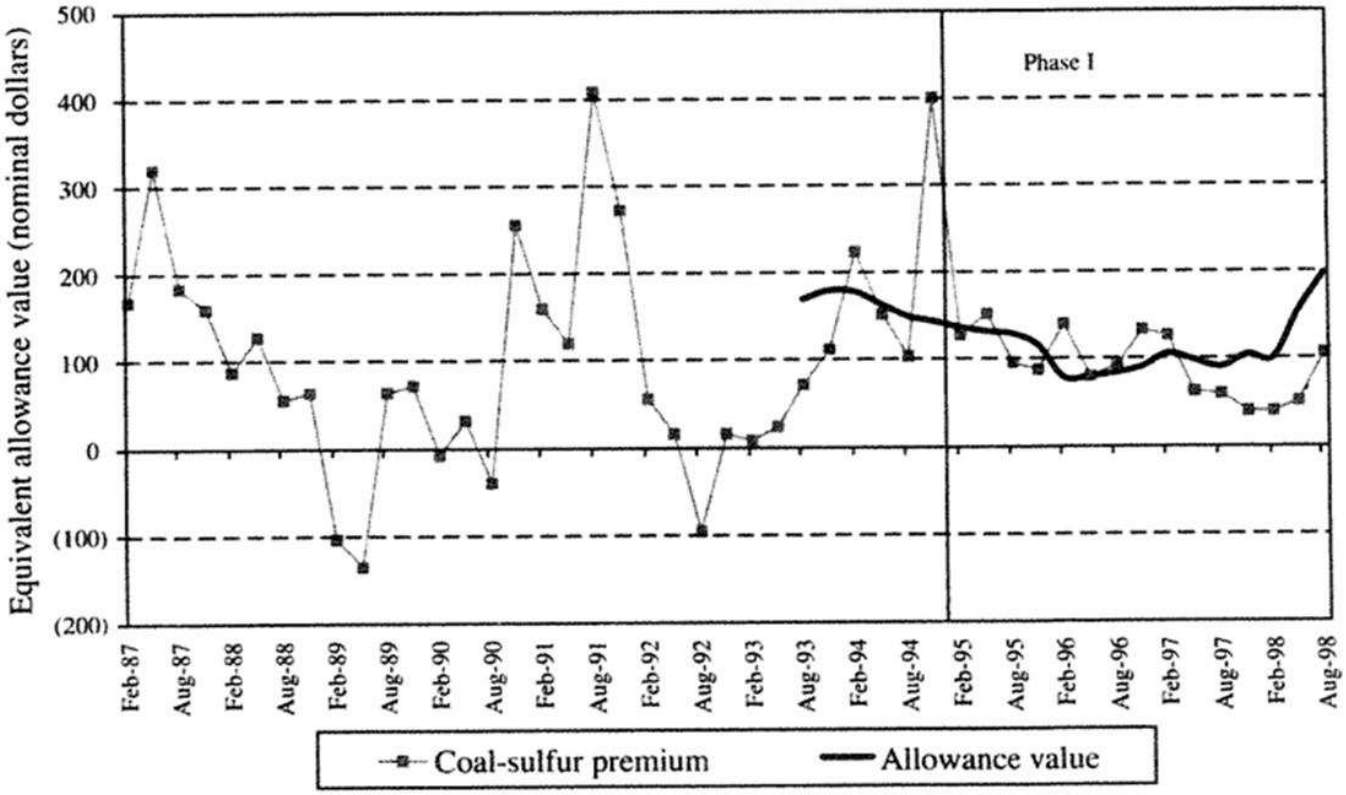


Figure 10.1. Allowance value vs. coal-sulfur premium, central Appalachia, 12,500 Btu/lb, 1.5 to 2.0 lb/mmBtu.

Source: Fieldston (1997, 1998).

Lessons

- Trading can work
  - ▷ Estimated cost savings relative to command-and-control regulation $20 billion in PV in 1995 dollars
- Politics need not mess things up but did at the end
- Markets can develop
  - ▷ Coal bundled with permits
  - ▷ With a contract for 2.5 lb/mmBtu coal, may deliver higher, but if so accompanied by allowances to make it equivalent
- Trading handles surprises (expansion of PRB coal)
- Extrapolate with care
  - ▷ Once-and-for-all reduction
  - ▷ Relatively small number of large sources
  - ▷ Monitoring feasible

Future

- NO_x trading in place
- Cap and trade for GHG on the horizon
- Regional GHG trading started in the Northeast