

# Lecture 7: Externalities

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## OUTLINE

Second part of course is going to cover market failures and show how government interventions can help

- 1) Externalities and public goods
- 2) Asymmetric information (social insurance)

## EXTERNALITIES

**Market failure:** A problem that violates one of the assumptions of the 1st welfare theorem and causes the market economy to deliver an outcome that does not maximize efficiency

**Externality:** Externalities arise whenever the actions of one economic agent **directly** affect another economic agent outside the market mechanism

Externality example: a steel plant that pollutes a river used for recreation

Not an externality example: a steel plant uses more electricity and bids up the price of electricity for other electricity customers

Externalities are one important case of market failure

# EXTERNALITY THEORY: ECONOMICS OF NEGATIVE PRODUCTION EXTERNALITIES

**Negative production externality:** When a firm's production reduces the well-being of others who are not compensated by the firm.

**Private marginal cost (PMC):** The direct cost to producers of producing an additional unit of a good

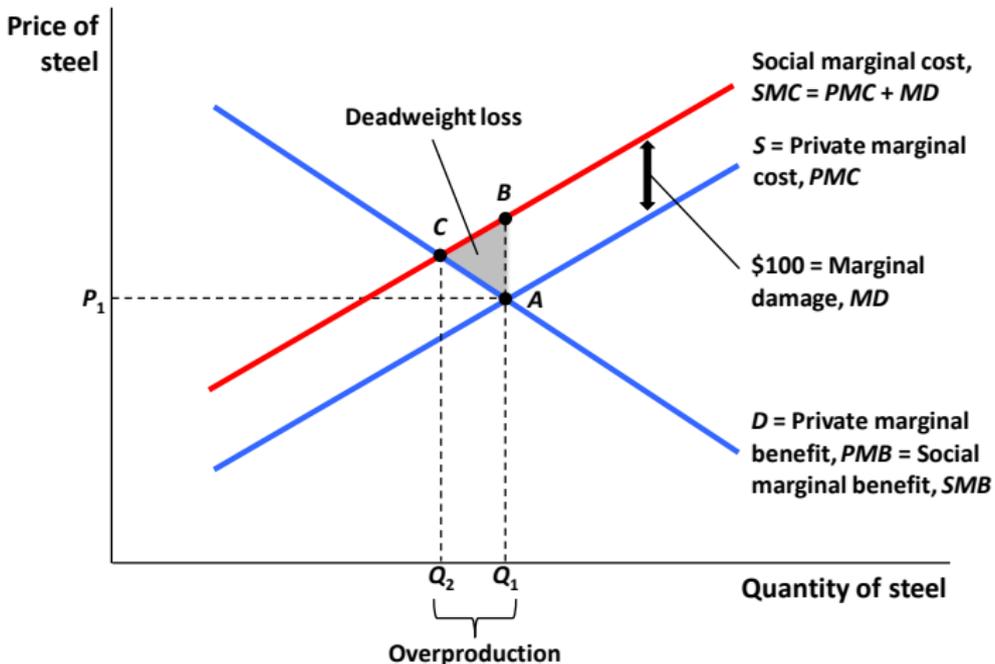
**Marginal Damage (MD):** Any additional costs associated with the production of the good that are imposed on others but that producers do not pay

**Social marginal cost (SMC = PMC + MD):** The private marginal cost to producers plus marginal damage

Example: steel plant pollutes a river but plant does not face any pollution regulation (and hence ignores pollution when deciding how much to produce)

## 5.1

# Economics of Negative Production Externalities: Steel Production



## EXTERNALITY THEORY: ECONOMICS OF NEGATIVE CONSUMPTION EXTERNALITIES

**Negative consumption externality:** When an individual's consumption reduces the well-being of others who are not compensated by the individual.

**Private marginal cost (PMB):** The direct benefit to consumers of consuming an additional unit of a good by the consumer.

**Social marginal cost (SMB):** The private marginal benefit to consumers plus any costs associated with the consumption of the good that are imposed on others

Example: Using a car and emitting carbon contributing to global warming

## 5.1

## APPLICATION: The Externality of SUVs

The consumption of large cars such as SUVs produces three types of negative externalities:

1. Environmental externalities: Compact cars get 25 miles/gallon, but SUVs get only 20.
2. Wear and tear on roads: Larger cars wear down the roads more.
3. Safety externalities: The odds of having a fatal accident quadruple if the accident is with a typical SUV and not with a car of the same size.

## Externality Theory: Positive Externalities

**Positive production externality:** When a firm's production increases the well-being of others but the firm is not compensated by those others.

Example: Beehives of honey producers have a positive impact on pollination and agricultural output

**Positive consumption externality:** When an individual's consumption increases the well-being of others but the individual is not compensated by those others.

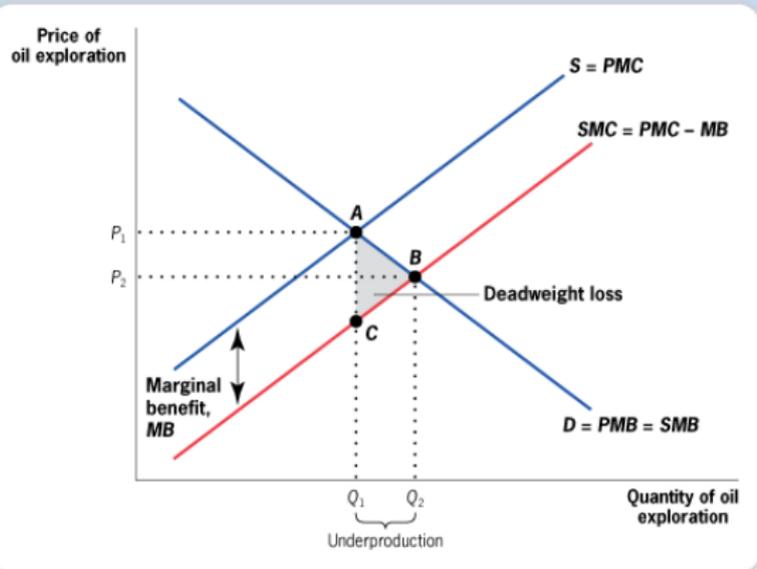
Example: Beautiful private garden that passers-by enjoy seeing

## 5.1

## Externality Theory

## Positive Externalities

■ FIGURE 5-4



**Market Failure Due to Positive Production Externality in the Oil Exploration Market** • Expenditures on oil exploration by any company have a positive externality because they offer more profitable opportunities for other companies. This leads to a social marginal cost that is below the private marginal cost, and a social optimum quantity ( $Q_2$ ) that is greater than the competitive market equilibrium quantity ( $Q_1$ ). There is underproduction of  $Q_2 - Q_1$ , with an associated deadweight loss of area ABC.

## Externality Theory: Market Outcome is Inefficient

With a free market, quantity and price are such that  $PMB = PMC$

Social optimum is such that  $SMB = SMC$

⇒ Private market leads to an inefficient outcome (1st welfare theorem does not work)

Negative production externalities lead to over production

Positive production externalities lead to under production

Negative consumption externalities lead to over consumption

Positive consumption externalities lead to under consumption

## Private-Sector Solutions to Negative Externalities

Key question raised by Ronald Coase (famous Nobel Prize winner Chicago libertarian economist):

Are externalities really outside the market mechanism?

**Internalizing the externality:** When either private negotiations or government action lead the price to the party to fully reflect the external costs or benefits of that party's actions.

## PRIVATE-SECTOR SOLUTIONS TO NEGATIVE EXTERNALITIES: COASE THEOREM

**Coase Theorem (Part I):** When there are well-defined property rights and costless bargaining, then negotiations between the party creating the externality and the party affected by the externality can bring about the socially optimal market quantity.

**Coase Theorem (Part II):** The efficient quantity for a good producing an externality does not depend on which party is assigned the property rights, as long as someone is assigned those rights.

## COASE THEOREM EXAMPLE

Firms pollute a river enjoyed by individuals. If firms ignore individuals, there is too much pollution

**1) Individuals own river:** If river is owned by individuals then individuals can charge firms for polluting the river. They will charge firms the marginal damage (MD) per unit of pollution.

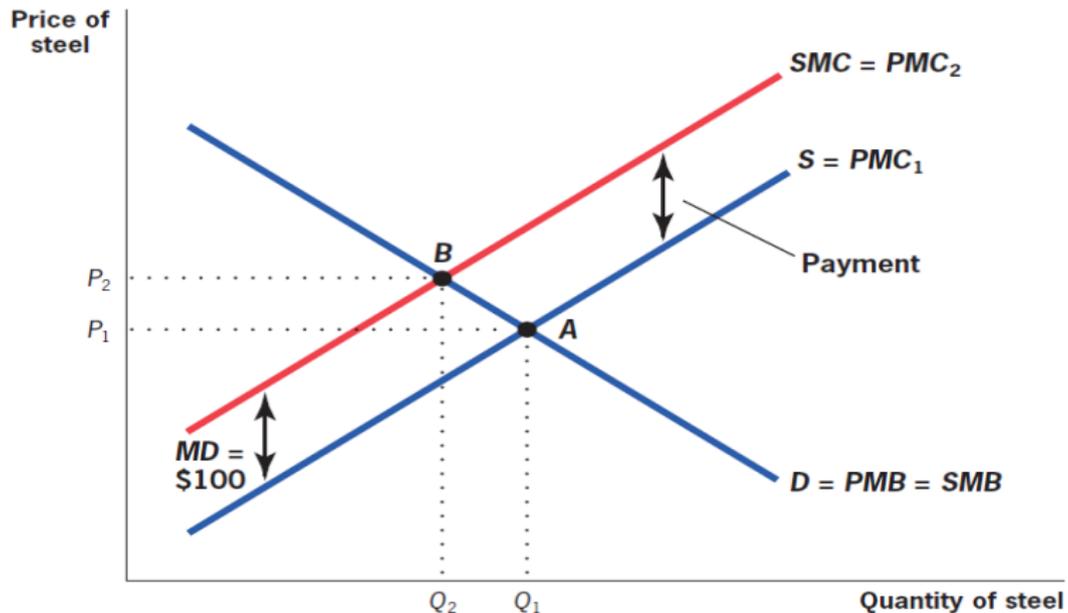
Why price pollution at MD? If price is above MD, individuals would want to sell an extra unit of pollution, so price must fall. MD is the equilibrium efficient price in the newly created pollution market.

**2) Firms own river:** If river is owned by firms then firm can charge individuals for polluting less. They will also charge individuals the MD per unit of pollution reduction.

Final level of pollution will be the same in 1) and 2)

## 5.2

## The Solution: Coasian Payments



## PROBLEMS WITH COASIAN SOLUTION

In practice, the Coase theorem is unlikely to solve many of the types of externalities that cause market failures.

**1) The assignment problem:** In cases where externalities affect many agents (e.g. global warming), assigning property rights is difficult

⇒ Coasian solutions are likely to be more effective for small, localized externalities than for larger, more global externalities involving large number of people and firms

**2) The holdout problem:** Shared ownership of property rights gives each owner power over all the others (because joint owners have to all agree to the Coasian solution)

As with the assignment problem, the holdout problem would be amplified with an externality involving many parties.

## PROBLEMS WITH COASIAN SOLUTION

**3) Transaction Costs and Negotiating Problems:** The Coasian approach ignores the fundamental problem that it is hard to negotiate when there are large numbers of individuals on one or both sides of the negotiation.

This problem is amplified for an externality such as global warming, where the potentially divergent interests of billions of parties on one side must be somehow aggregated for a negotiation.

## PROBLEMS WITH COASIAN SOLUTION: BOTTOM LINE

Ronald Coase's insight that externalities can sometimes be internalized was useful.

It provides the competitive market model with a defense against the onslaught of market failures.

It is also an excellent reason to suspect that the market may be able to internalize some small-scale, localized externalities.

It won't help with large-scale, global externalities, where only a "government" can successfully aggregate the interests of all individuals suffering from externality

## Public Sector Remedies For Externalities

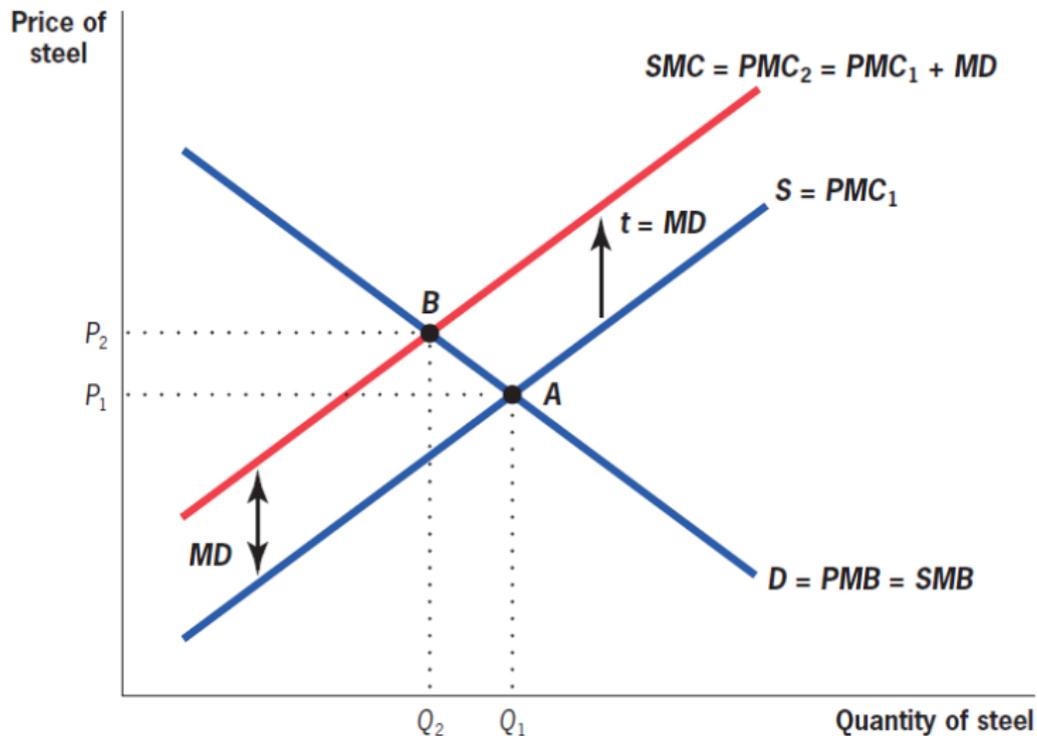
The Environmental Protection Agency (EPA) was formed in 1970 to provide public-sector solutions to the problems of externalities in the environment.

Public policy makers employ two types of remedies to resolve the problems associated with negative externalities:

- 1) **price policy:** corrective tax or subsidy equal to marginal damage per unit
- 2) **quantity regulation:** government forces firms to produce the socially efficient quantity

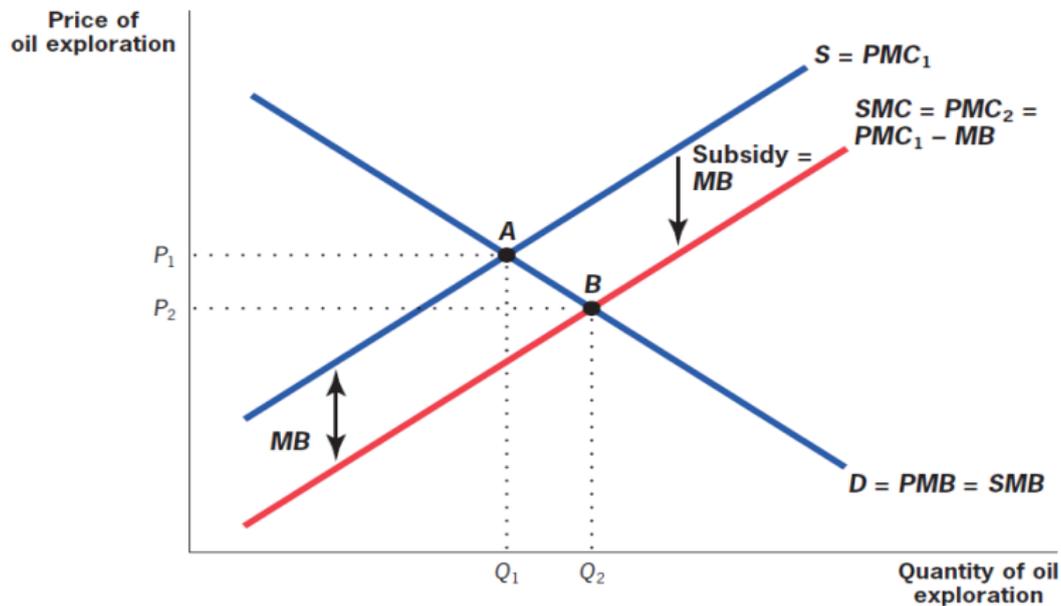
## 5.3

## Corrective Taxation



## 5.3

## Corrective Subsidies



## PUBLIC SECTOR REMEDIES FOR EXTERNALITIES: REGULATION

In an ideal world, Pigouvian taxation and quantity regulation would be identical

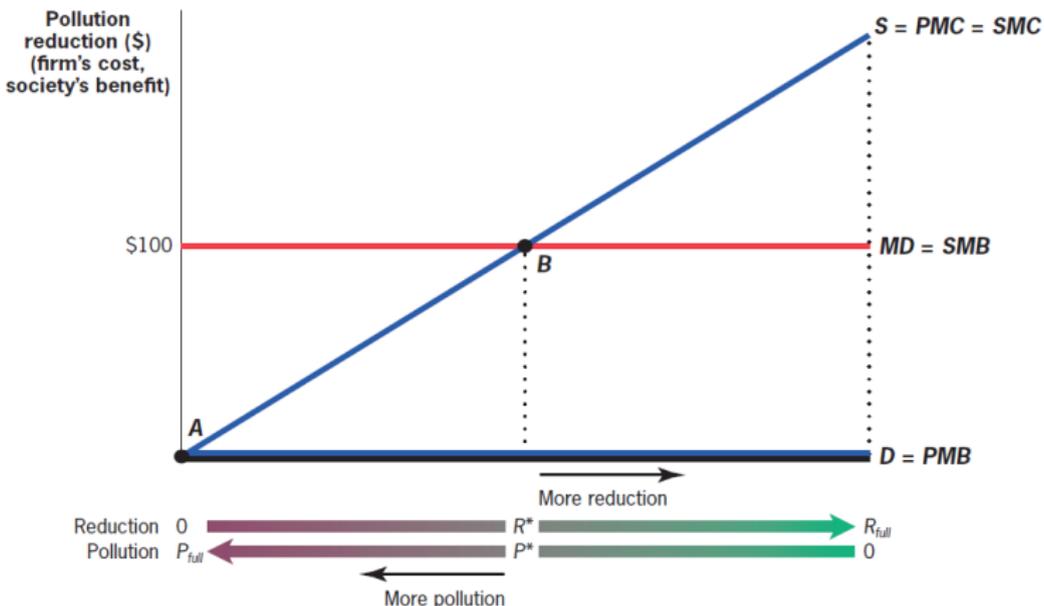
Quantity regulation seems more straightforward, hence, it has been the traditional choice for addressing environmental externalities

In practice, there are complications that may make taxes a more effective means of addressing externalities.

The only way to reduce an externality, e.g., pollution, is not to cut down on production. Think of a “pollution reduction” technology (many examples).

## 5.4

## Distinctions Between Price and Quantity Approaches to Addressing Externalities: Basic Model



## MODEL WITH HETEROGENEOUS COSTS

Assume MD of pollution is \$1 per unit of pollution

2 firms with low ( $L$ ) or high ( $H$ ) cost of pollution reduction  $q$ :

$$c_H(q) = 1.5q^2 \Rightarrow MC_H(q) = c'_H(q) = 3q$$

$$c_L(q) = .75q^2 \Rightarrow MC_L(q) = c'_L(q) = 1.5q$$

With no taxes, no regulations, firms do  $q_L = q_H = 0$

Social welfare maximization:

$$V = \max_{q_H, q_L} q^H + q^L - c_H(q^H) - c_L(q^L) \Rightarrow$$

$$MC_H = 1, MC_L = 1 \Rightarrow q^H = 1/3, q^L = 2/3$$

Optimum outcome is to have the low cost firm do more pollution reduction than the high cost firm

## TAX VERSUS REGULATION SOLUTION

Socially optimal outcome can be achieved by \$1 tax per unit of pollution (same tax across firms):

Firm  $H$  chooses  $q_H$  to maximize  $q^H - c_H(q^H) \Rightarrow MC_H = 1$

Firm  $L$  chooses  $q_L$  to maximize  $q^L - c_L(q^L) \Rightarrow MC_L = 1$

Uniform quantity regulation  $q^H = q^L = 1/2$  is not efficient because firm  $H$  has higher  $MC$  of polluting than firm  $L$ :

Proof: Firm  $H$  would be happy to pay firm  $L$  to reduce  $q^L$  and increase  $q^H$  to keep  $q^L + q^H = 1$ , firm  $L$  is happier and society has same level of pollution

## Quantity Regulation with Trading Permits

Suppose start with quantity regulation  $q_0^H = q_0^L = 1/2$  and allow firms to trade pollution reductions as long as  $q^H + q^L = 1$

Generates a market for pollution reduction at price  $p$

Firm  $H$  maximizes  $pq^H - c_H(q^H) \Rightarrow MC_H = p$  and  $q^H = p/3$

Firm  $L$  maximizes  $pq^L - c_L(q^L) \Rightarrow MC_L = p$  and  $q^L = 2p/3$

$\Rightarrow q^H + q^L = p$ . As  $1 = q_0^L + q_0^H = q^H + q^L$ , in equilibrium  $p = 1$  and hence  $q_H = 1/3$  and  $q_L = 2/3$

Final outcome  $q_H, q_L$  does not depend on initial regulation  $q_0^H, q_0^L$

Quantity regulation with tradable permits is efficient as long as total quantity  $q_0^L + q_0^H = 1$

## MULTIPLE PLANTS WITH DIFFERENT REDUCTION COSTS

Policy Option 1: Quantity Regulation (not efficient unless quantity can be based on actual reduction cost for each firm)

Policy Option 2: Price Regulation Through a Corrective Tax (efficient)

Policy Option 3: Quantity Regulation with Tradable Permits (efficient)

## CORRECTIVE TAXES VS. TRADABLE PERMITS

Two differences between corrective taxes and tradable permits (carbon tax vs. cap-and-trade in the case of CO<sub>2</sub> emissions)

**1) Initial allocation of permits:** If the government sells them to firms, this is equivalent to the tax

If the government gives them to current firms for free, this is like the tax + large transfer to initial polluting firms.

**2) Uncertainty in marginal costs:** With uncertainty in costs of reducing pollution, tax cannot target a specific quantity while tradable permits can  $\Rightarrow$  two policies no longer equivalent.

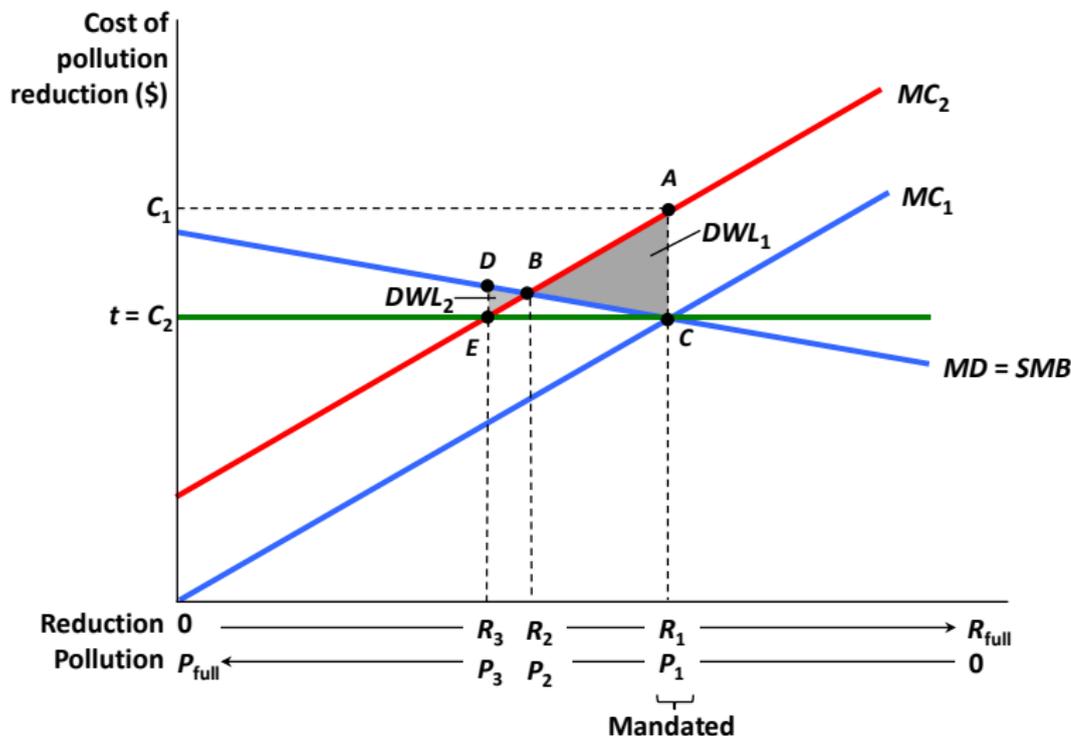
Taxes preferable when MD curve is flat. Tradable permits are preferable when MD curve is steep.

If critical to get quantity right  $\rightarrow$  quantity regulation (when MD steep).

If critical to minimize costs  $\rightarrow$  set tax (cost will be limited to the tax).

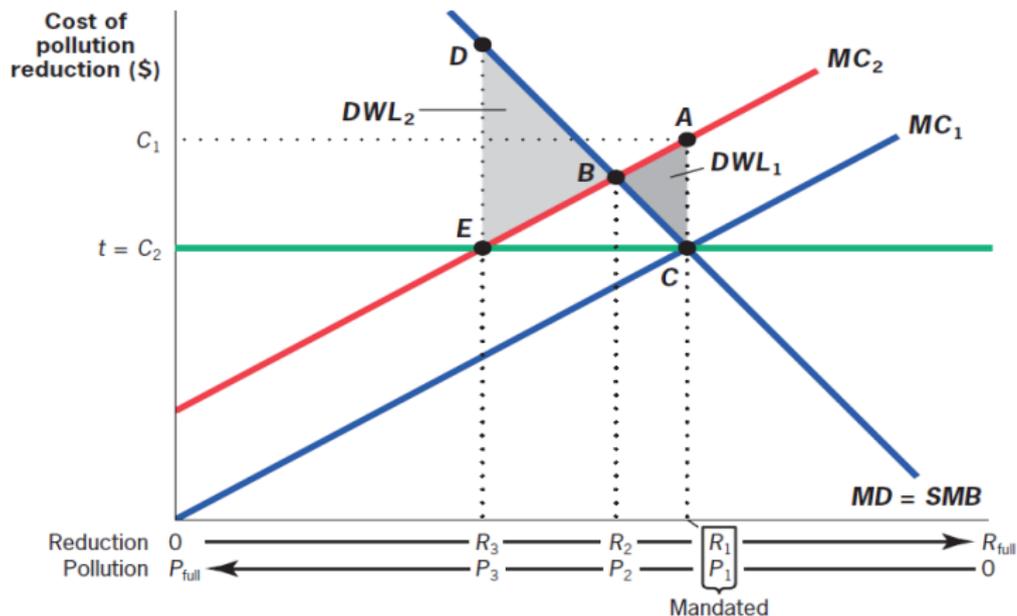
## 5.4

# Uncertainty About Costs of Reduction: Case 1: Flat $MD$ Curve (Global Warming)



## 5.4

# Uncertainty About Costs of Reduction: Case 2: Steep MD Curve (Nuclear leakage)



## Empirical Example: Acid Rain and Health

Acid rain due to contamination by emissions of sulfur dioxide ( $SO_2$ ) and nitrogen oxide ( $NO_x$ ).

**1970 Clean Air Act:** Landmark federal legislation that first regulated acid rain-causing emissions by setting maximum standards for atmospheric concentrations of various substances, including  $SO_2$ .

**The 1990 Amendments and Emissions Trading:**

$SO_2$  allowance system: The feature of the 1990 amendments to the Clean Air Act that granted plants permits to emit  $SO_2$  in limited quantities and allowed them to trade those permits.

## Empirical Example: Effects of Clean Air Act of 1970

How does acid rain (or SO<sub>2</sub>) affect health?

Observational approach: relate mortality in a geographical area to the level of particulates (such as SO<sub>2</sub>) in the air

Problem: Areas with more particulates may differ from areas with fewer particulates in many other ways, not just in the amount of particulates in the air

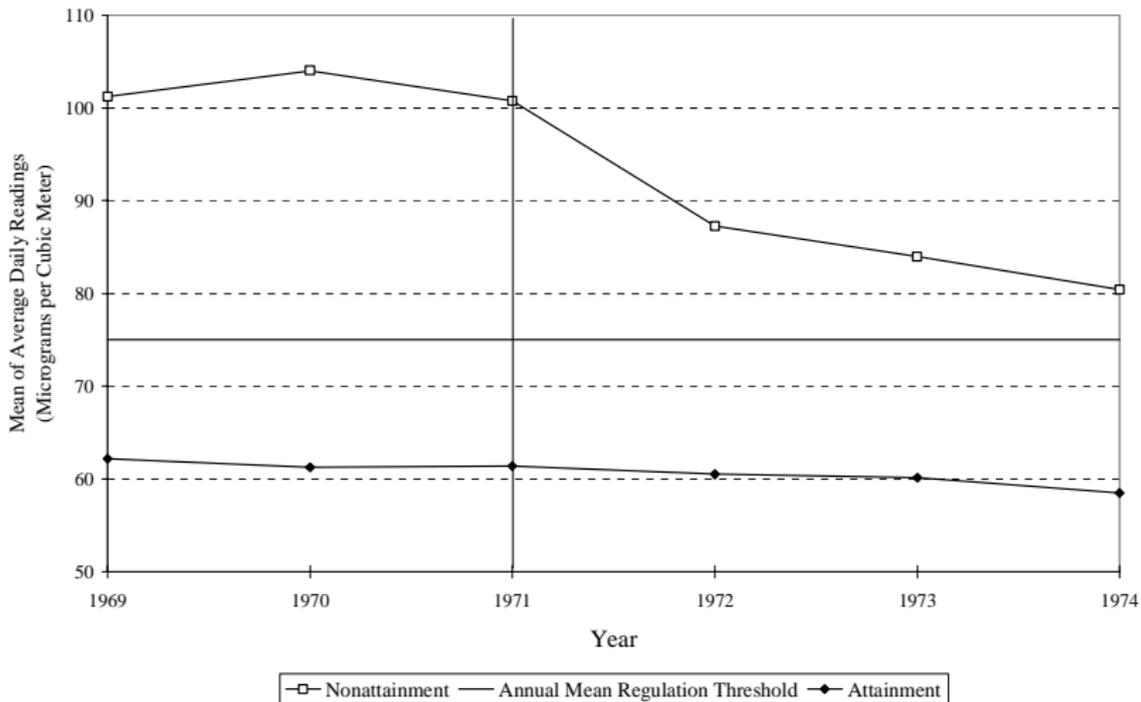
Chay and Greenstone (2003) use clean air act of 1970 to resolve the causality problem:

Areas with more particulates than threshold required to clean up air [treatment group]. Areas with less particulates than threshold are control group.

Compares infant mortality across 2 types of places before and after (DD approach)

Figure 2: Trends in TSPs Pollution and Infant Mortality, by 1972 Nonattainment Status

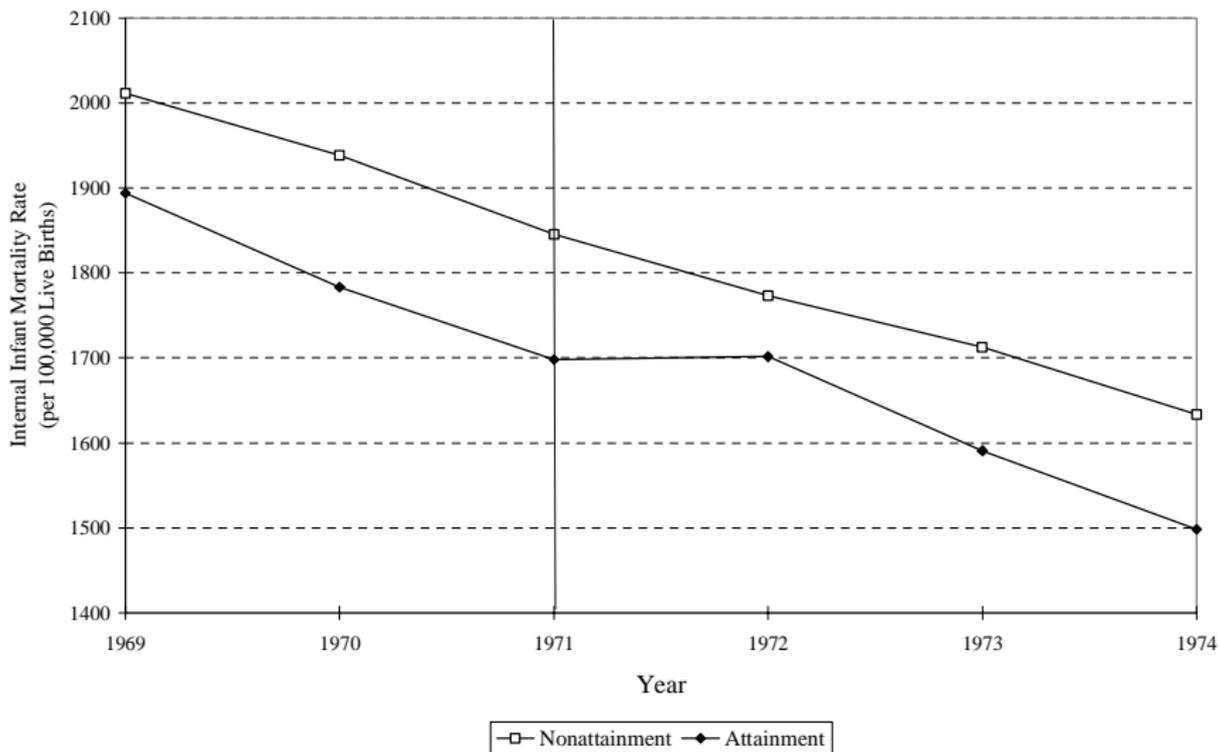
A. Trends in Mean TSPs Concentrations, by 1972 Nonattainment Status



Source: Authors' tabulations from EPA's "Quick Look Reports" data file.

Source: Chay and Greenstone (2003)

## B. Trends in Internal Infant Mortality Rate, by 1972 Nonattainment Status



Source: Chay and Greenstone (2003)

## Climate Change and CO2 Emissions

Industrialization has dramatically increased CO2 emissions and atmospheric CO2 generates global warming

Four factors make this challenging (Wagner-Weitzman 2015):

- 1) **Global:** Emissions in one country affect the full world
- 2) **Irreversible:** Atmospheric CO2 has long life (35% remains after 100 years) [absent carbon capture tech breakthrough]
- 3) **Long-term:** Costs of global warming are decades/centuries away [how should this be discounted?]
- 4) **Uncertain:** Great uncertainty in costs of global warming [mitigation or amplifying feedback loops]

How fast should we start reducing emissions? [Stern-Weitzman want a fast reduction, Nordhaus advocates a slower path]

## Main costs of global warming

Enormous variation across geographical areas and economic development.  
Pace of change makes adaptation daunting

1) Sea rise which will flood low lying coasts and major population centers (e.g., Miami, Florida; value of real estate subject to regular flooding has dropped)

2) Impact on bio-diversity (mass extinctions)

3) Agricultural production could be disrupted by climate change and the increased weather variability it generates:

demand for food is very inelastic in the short-run  $\Rightarrow$  Spikes in prices if ag output falls  $\Rightarrow$  disruption/famines possible in low income countries

4) Droughts and heat waves will make many places less livable

## Empirical Example: Costs of Global Warming

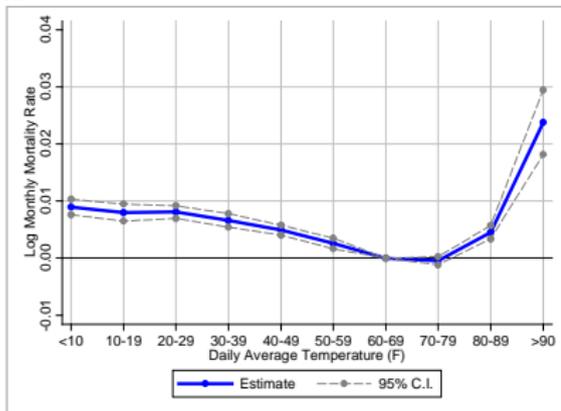
Estimating costs of Global warming is daunting because society will adapt and reduce costs (relative to a scenario with no adaptation)

Example: heat waves and mortality analysis of Barreca et al. (2016)

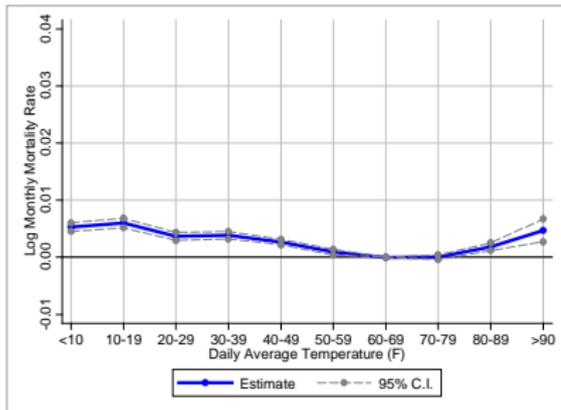
- 1) The mortality effect of an extremely hot day ( $80^{\circ}\text{F}+$ ) declined by about 75% between 1900-1959 and 1960-2004.
- 2) Adoption of residential air conditioning (AC) explains the entire decline
- 3) Worldwide adoption of AC will speed up the rate of climate change (if fossil fuel powered)

Figure 2: Estimated Temperature-Mortality Relationship (Continued)

(c) 1929-1959



(d) 1960-2004



**Notes:** Figure 2 plots the response function between log monthly mortality rate and average daily temperatures, obtained by fitting Equation (1). The response function is normalized with the 60°F – 69°F category set equal to zero so each estimate corresponds to the estimated impact of an additional day in bin  $j$  on the log monthly

## CURBING GLOBAL WARMING: KYOTO TREATY

Kyoto 1997: 35 industrialized nations (but not US) agreed to reduce their emissions of greenhouse gases to 5% below (depends on country) 1990 levels by the year 2012

Industrialized countries are allowed to trade emissions rights **among themselves**, as long as the total emissions goals are met [=quantity regulation with trading permits]

Developing countries are not in the treaty even though it is cheaper to use fuel efficiently as you develop an industrial base than it is to “retrofit” an existing industrial base

## CURBING GLOBAL WARMING: FUTURE

In principle, reducing CO<sub>2</sub> emissions could generate Pareto improvement bc losers from global warming lose more in \$ than what emitters win from emitting

Challenge: in practice, remedies (such as carbon tax) create losers who oppose change

Disagreement between rich and developing countries on who should bear the cost of curbing greenhouse gas emissions

In the US, Obama directed EPA to regulate CO<sub>2</sub> emission [carbon tax or cap-and-trade requires congress law] but this was undone by Trump

Higher price on carbon emissions [through taxes or trading permits] will be needed to curb emissions and global warming. Participation of the US and large devo countries (China, India) will be needed [Nordhaus 2013 and Wagner-Weitzman books]

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