

# Externalities: Problems and Solutions

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# OUTLINE

## Chapter 5

### 5.1 Externality Theory

### 5.2 Private-Sector Solutions to Negative Externalities

### 5.3 Public-Sector Remedies for Externalities

### 5.4 Distinctions Between Price and Quantity Approaches to Addressing Externalities

### 5.5 Conclusion

## **EXTERNALITIES: PROBLEMS AND SOLUTIONS**

**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 make another economic agent worse or better off, yet the first agent neither bears the costs nor receives the benefits of doing so:

Example: a steel plant that pollutes a river used for recreation

Externalities are one example 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

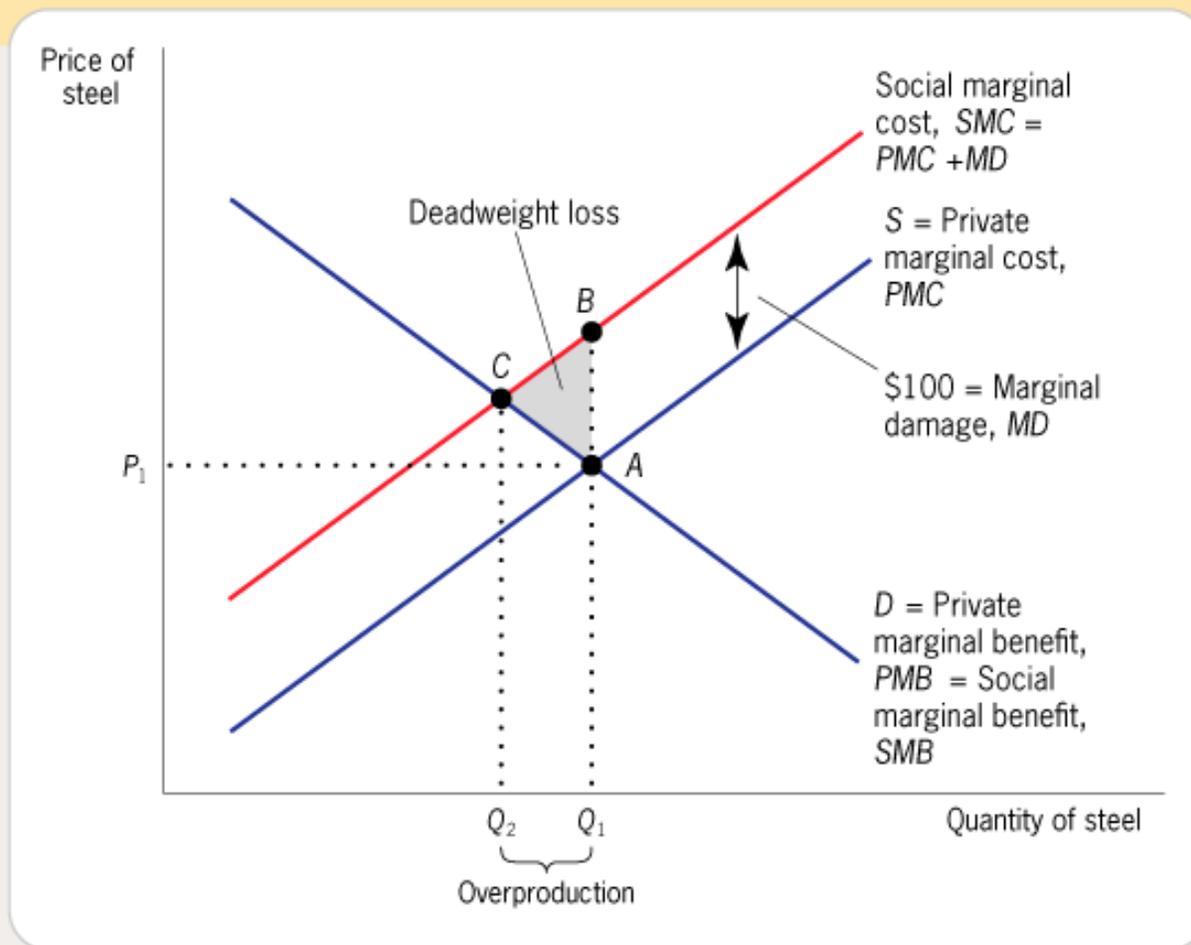
Example: steel plant pollutes a river but plant does not face any pollution regulation (and hence ignores pollution when deciding how much to produce)

## - 5.1

# Externality Theory

## Economics of Negative Production Externalities

■ FIGURE 5-2



**Market Failure Due to Negative Production Externalities in the Steel Market** • A negative production externality of \$100 per unit of steel produced (marginal damage,  $MD$ ) leads to a social marginal cost that is above the private marginal cost, and a social optimum quantity ( $Q_2$ ) that is lower than the competitive market equilibrium quantity ( $Q_1$ ). There is overproduction of  $Q_1 - Q_2$ , with an associated deadweight loss of area  $BCA$ .

# 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.

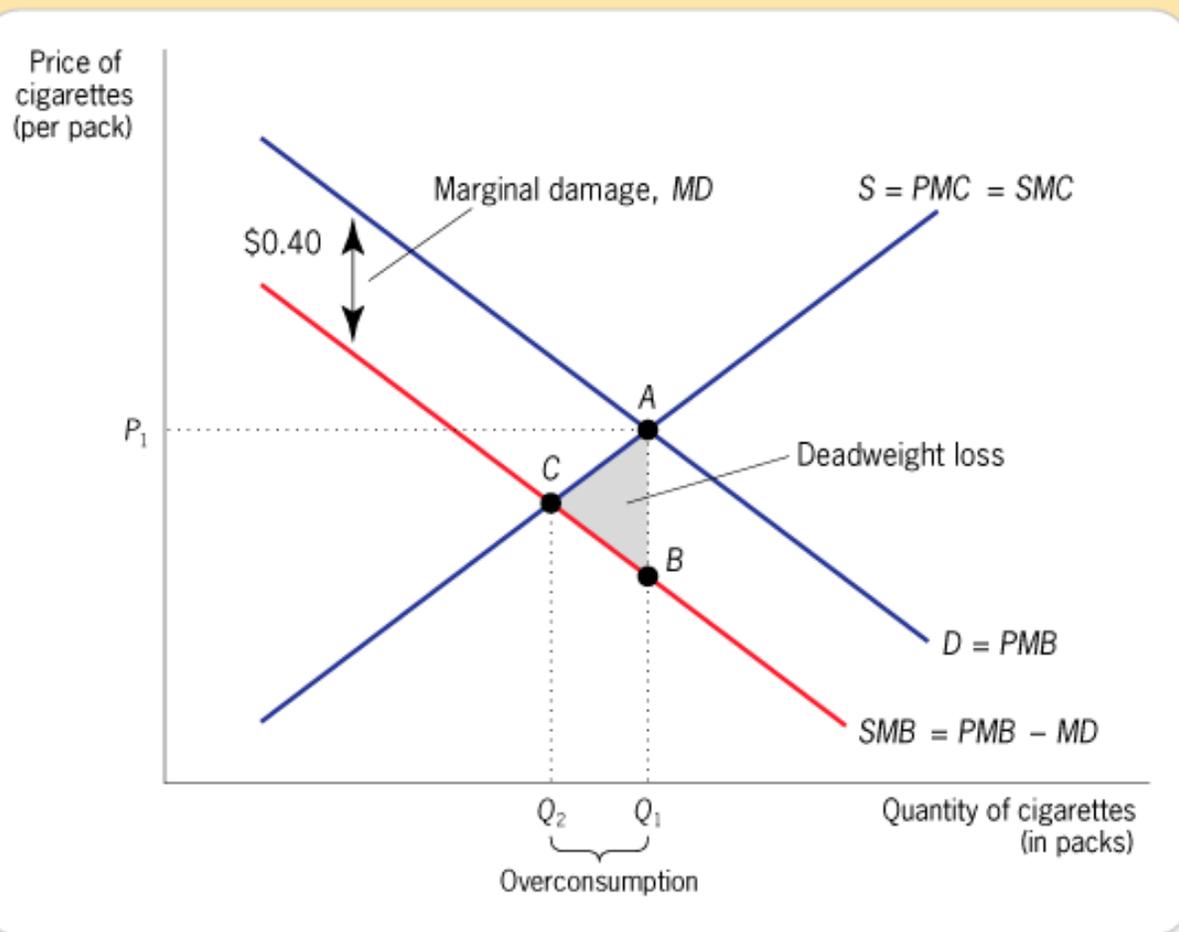
**Social marginal cost (SMB):** The private marginal benefit to consumers plus any costs associated with the consumption of the good that are imposed on others

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

# Externality Theory

## Negative Consumption Externalities

■ FIGURE 5-3



Market Failure Due to Negative Consumption Externalities in the Cigarette Market • A negative consumption externality of 40¢ per pack of cigarettes consumed leads to a social marginal benefit that is below the private marginal benefit, and a social optimum quantity ( $Q_2$ ) that is lower than the competitive market equilibrium quantity ( $Q_1$ ). There is overconsumption  $Q_1 - Q_2$ , with an associated deadweight loss of area  $ACB$ .

## ▶ APPLICATION

### **The Externality of SUVs**

- ▶ The typical driver today is in a car that weighs 4,089 pounds. The major culprits in this evolution of car size are sport utility vehicles (SUVs) with an average weight size of 4,500 pounds.
- ▶ The consumption of large cars such as SUVs produces three types of negative externalities:
  - ▶ **Environmental Externalities:**
    - ▶ The contribution of driving to global warming is directly proportional to the amount of fossil fuel a vehicle requires to travel a mile. SUV drivers use more gas to go to work or run their errands, increasing fossil fuel emissions.
  - ▶ **Wear and Tear on Roads:**
    - ▶ Each year, federal, state, and local governments spend \$33.2 billion repairing our roadways. Damage to roadways comes from many sources, but a major culprit is the passenger vehicle, and the damage it does to the roads is proportional to vehicle weight.
  - ▶ **Safety Externalities:**
    - ▶ One major appeal of SUVs is that they provide a feeling of security because they are so much larger than other cars on the road. Offsetting this feeling of security is the added insecurity imposed on other cars on the road.

## 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

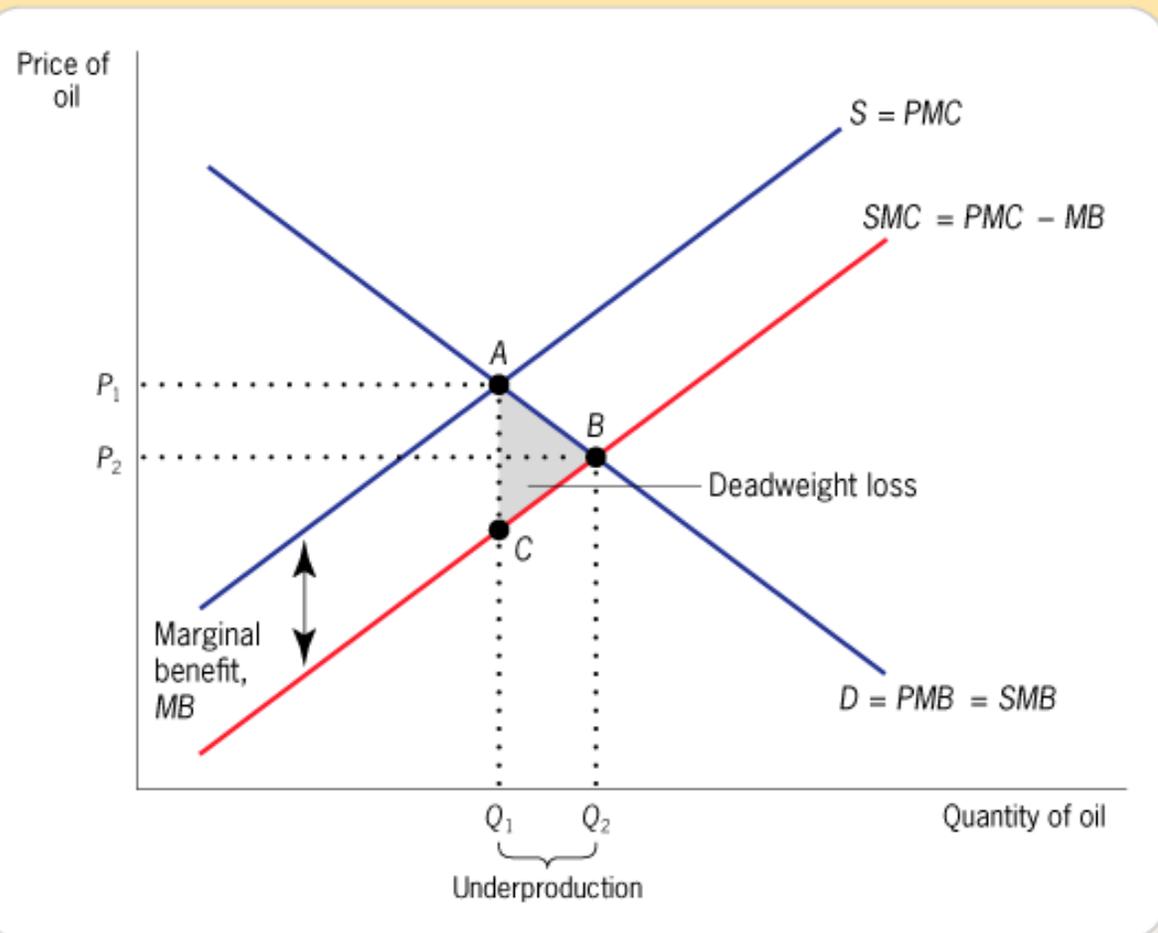
**Positive consumption externality:** When an individual's consumption increases the well-being of others but the individual is not compensated by those others.

Example: Beautiful private garden that passers-by enjoy seeing

# 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

## EXTERNALITY THEORY: GRAPHICAL ANALYSIS

One aspect of the graphical analysis of externalities is knowing which curve to shift, and in which direction. There are four possibilities:

- Negative production externality: SMC curve lies above PMC curve
- Positive production externality: SMC curve lies below PMC curve
- Negative consumption externality: SMB curve lies below PMB curve
- Positive consumption externality: SMB curve lies above PMB curve

The key is to assess which category a particular example fits into. First, you must assess whether the externality is associated with producing a good or with consuming a good. Then, you must assess whether the externality is positive or negative.

## 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 solution to 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 owners:** 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? Because this is the equilibrium efficient price in the newly created pollution market.

**2) Firms owners:** 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.

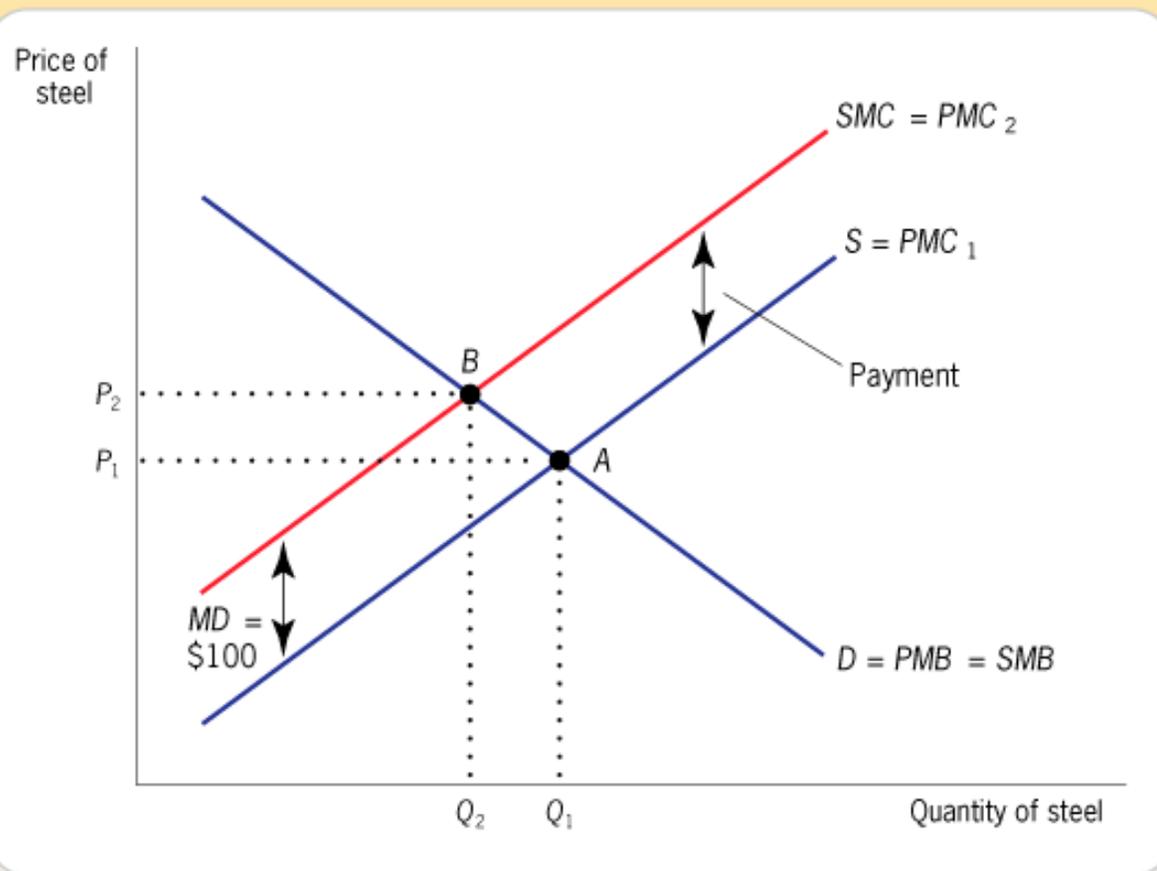
Final level of pollution will be the same in 1) and 2)

## - 5.2

# Private-Sector Solutions to Negative Externalities

## The Solution

■ FIGURE 5-5



A Coasian Solution to Negative Production Externalities in the Steel Market • If the fishermen charge the steel plant \$100 per unit of steel produced, this increases the plant's private marginal cost curve from  $PMC_1$  to  $PMC_2$ , which coincides with the  $SMC$  curve. The quantity produced falls from  $Q_1$  to  $Q_2$ , the socially optimal level of production. The charge internalizes the externality and removes the inefficiency of the negative externality.

# THE PROBLEMS WITH COASIAN SOLUTIONS

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  $\Rightarrow$  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.

## THE PROBLEMS WITH COASIAN SOLUTIONS

**3) The Free Rider Problem:** When an investment has a personal cost but a common benefit, individuals will underinvest (example: a single country is better off walking out of Kyoto protocol for carbon emission controls)

**4) 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.

## **THE PROBLEMS WITH COASIAN SOLUTIONS: 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

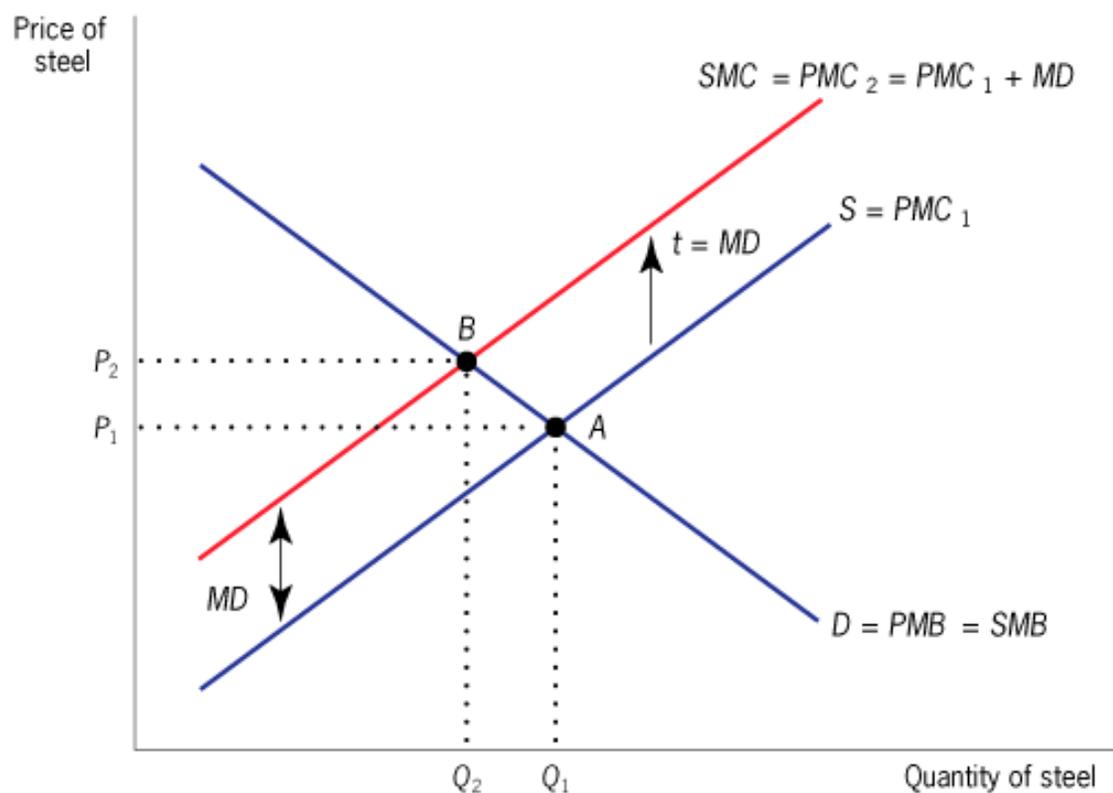
**2) quantity regulation:** government forces firms to produce the socially efficient quantity

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## Public-Sector Remedies for Externalities

## Corrective Taxation

■ FIGURE 5-6



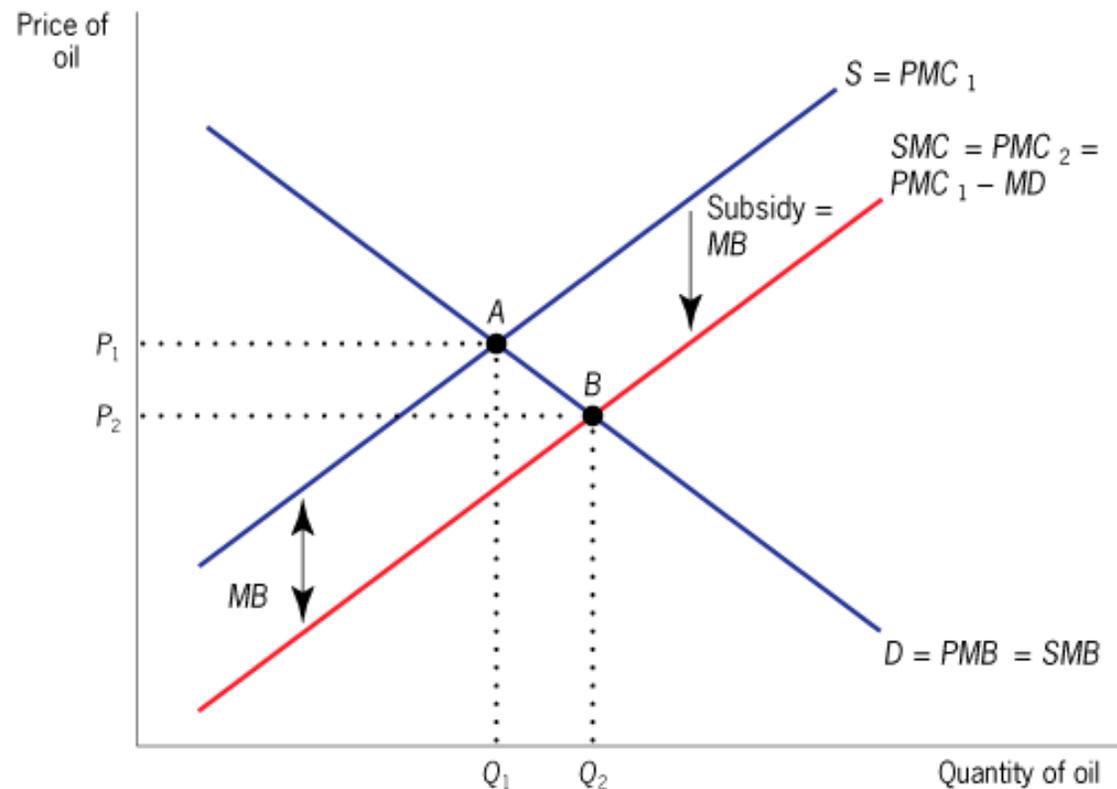
**Taxation as a Solution to Negative Production Externalities in the Steel Market** • A tax of \$100 per unit (equal to the marginal damage of pollution) increases the firm's private marginal cost curve from  $PMC_1$  to  $PMC_2$ , which coincides with the  $SMC$  curve. The quantity produced falls from  $Q_1$  to  $Q_2$ , the socially optimal level of production. Just as with the Coasian payment, this tax internalizes the externality and removes the inefficiency of the negative externality.

## - 5.3

## Public-Sector Remedies for Externalities

## Subsidies

■ FIGURE 5-7



Subsidies as a Solution to Positive Production Externalities in the Market for Oil Exploration • A subsidy that is equal to the marginal benefit from oil exploration reduces the oil producer's marginal cost curve from  $PMC_1$  to  $PMC_2$ , which coincides with the  $SMC$  curve. The quantity produced rises from  $Q_1$  to  $Q_2$ , the socially optimal level of production.

## **PUBLIC SECTOR REMEDIES FOR EXTERNALITIES: REGULATION**

In an ideal world, Pigouvian taxation and regulation would be identical. Because regulation appears much more straightforward, however, it has been the traditional choice for addressing environmental externalities in the United States and around the world.

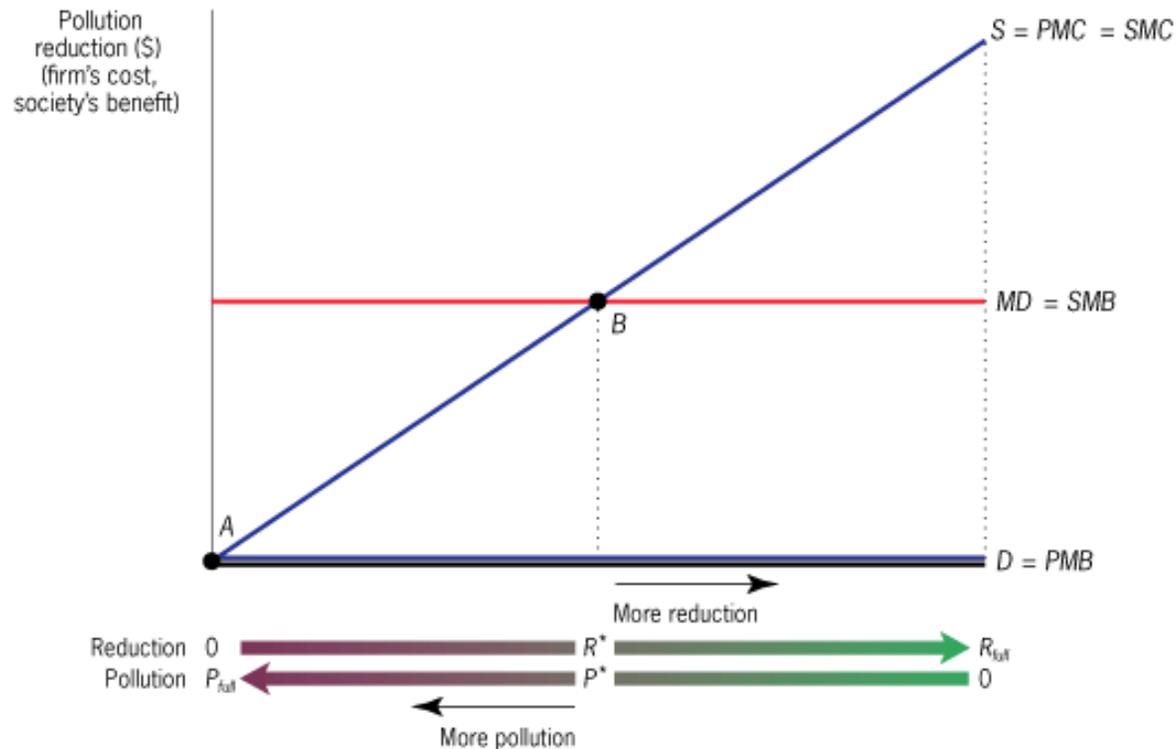
In practice, there are complications that may make taxes a more effective means of addressing externalities.

## - 5.4 -

# Distinctions Between Price and Quantity Approaches to Addressing Externalities

## Basic Model

■ FIGURE 5-8



**The Market for Pollution Reduction** • The marginal cost of pollution reduction ( $PMC = SMC$ ) is a rising function, while the marginal benefit of pollution reduction ( $SMB$ ) is (by assumption) a flat marginal damage curve. Moving from left to right, the amount of pollution reduction increases, while the amount of pollution falls. The optimal level of pollution reduction is  $R^*$ , the point at which these curves intersect. Since pollution is the complement of reduction, the optimal amount of pollution is  $P^*$ .

## 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  $q_0^H, q_0^L$

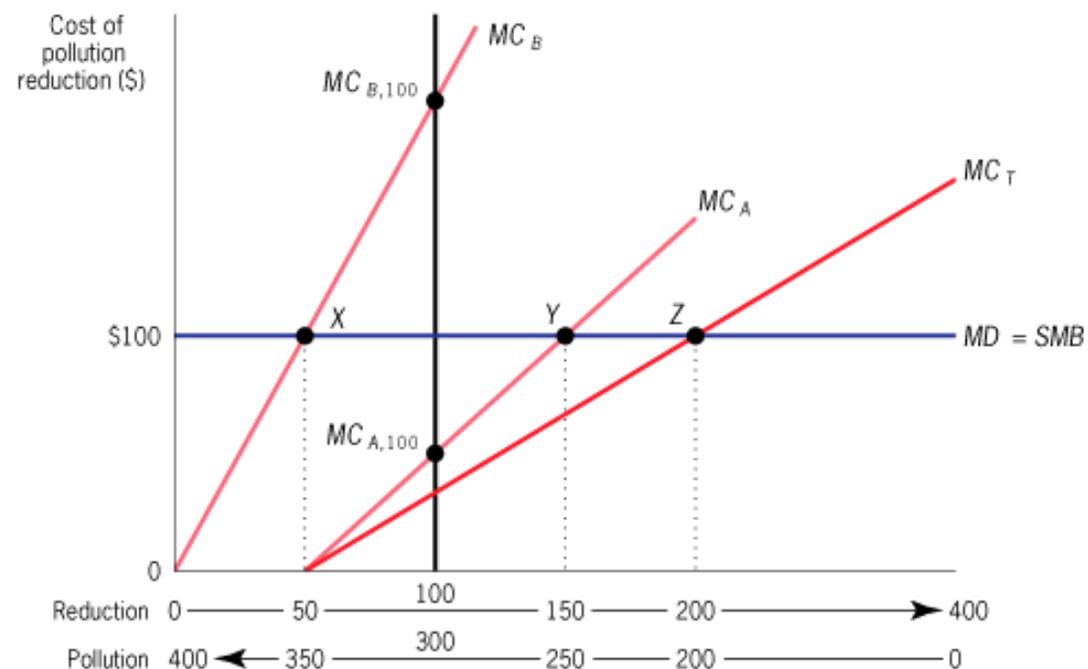
Quantity regulation with tradable permits is efficient as long as total quantity  $q_0^L + q_0^H = 1$

## 5.4

# Distinctions Between Price and Quantity Approaches to Addressing Externalities

## Multiple Plants with Different Reduction Costs

■ FIGURE 5-9



**Pollution Reduction with Multiple Firms** • Plant A has a lower marginal cost of pollution reduction at each level of reduction than does plant B. The optimal level of reduction for the market is the point at which the sum of marginal costs equals marginal damage (at point Z, with a reduction of 200 units). An equal reduction of 100 units for each plant is inefficient since the marginal cost to plant B ( $MC_B$ ) is so much higher than the marginal cost to plant A ( $MC_A$ ). The optimal division of this reduction is where each plant's marginal cost is equal to the social marginal benefit (which is equal to marginal damage). This occurs when plant A reduces by 150 units and plant B reduces by 50 units, at a marginal cost to each of \$100.

## **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.

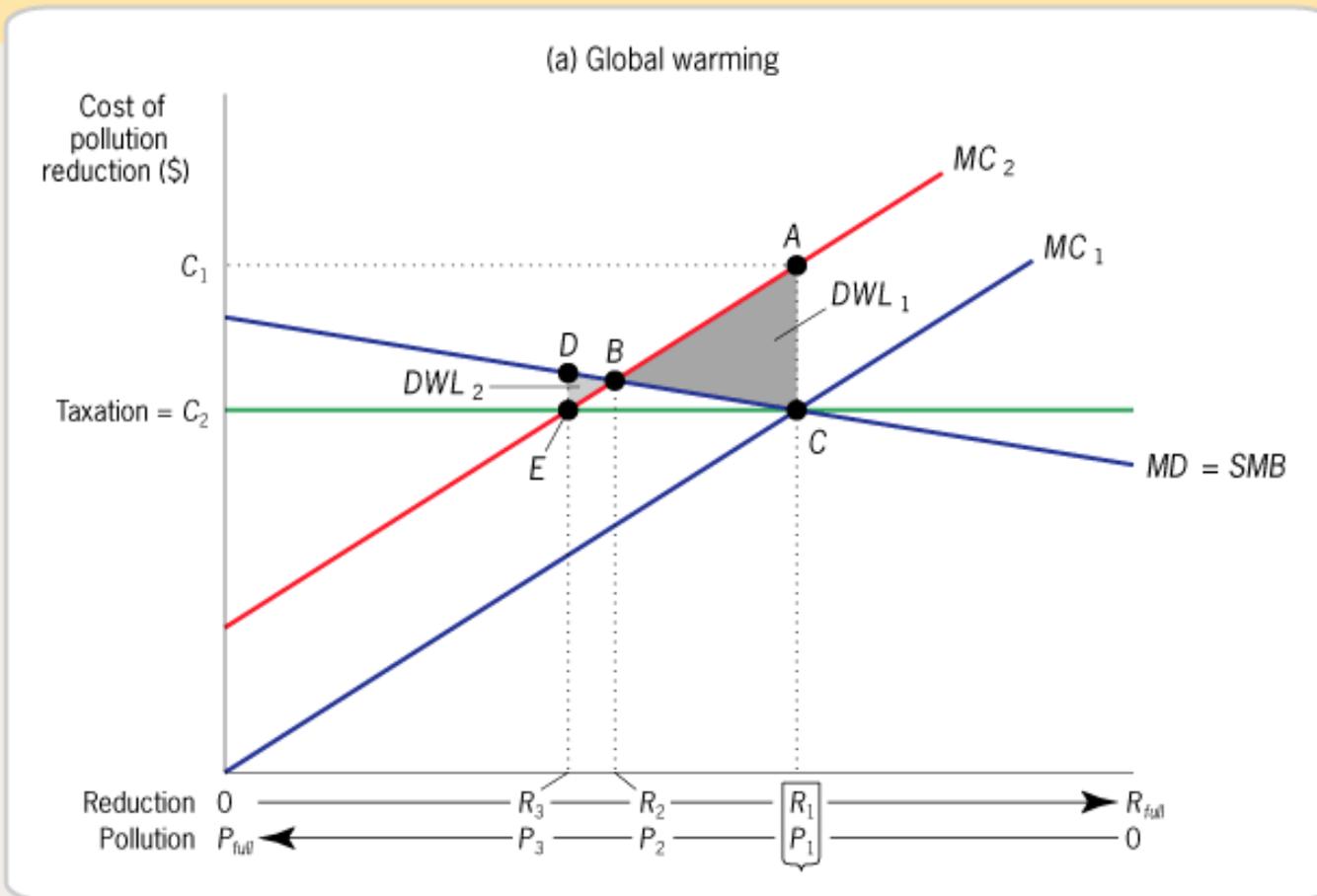
Taxes preferable when MD curve is flat. Tradable permits are preferable when MD curve is steep.

## - 5.4 -

# Distinctions Between Price and Quantity Approaches to Addressing Externalities

## Uncertainty About Costs of Reduction

■ FIGURE 5-10α



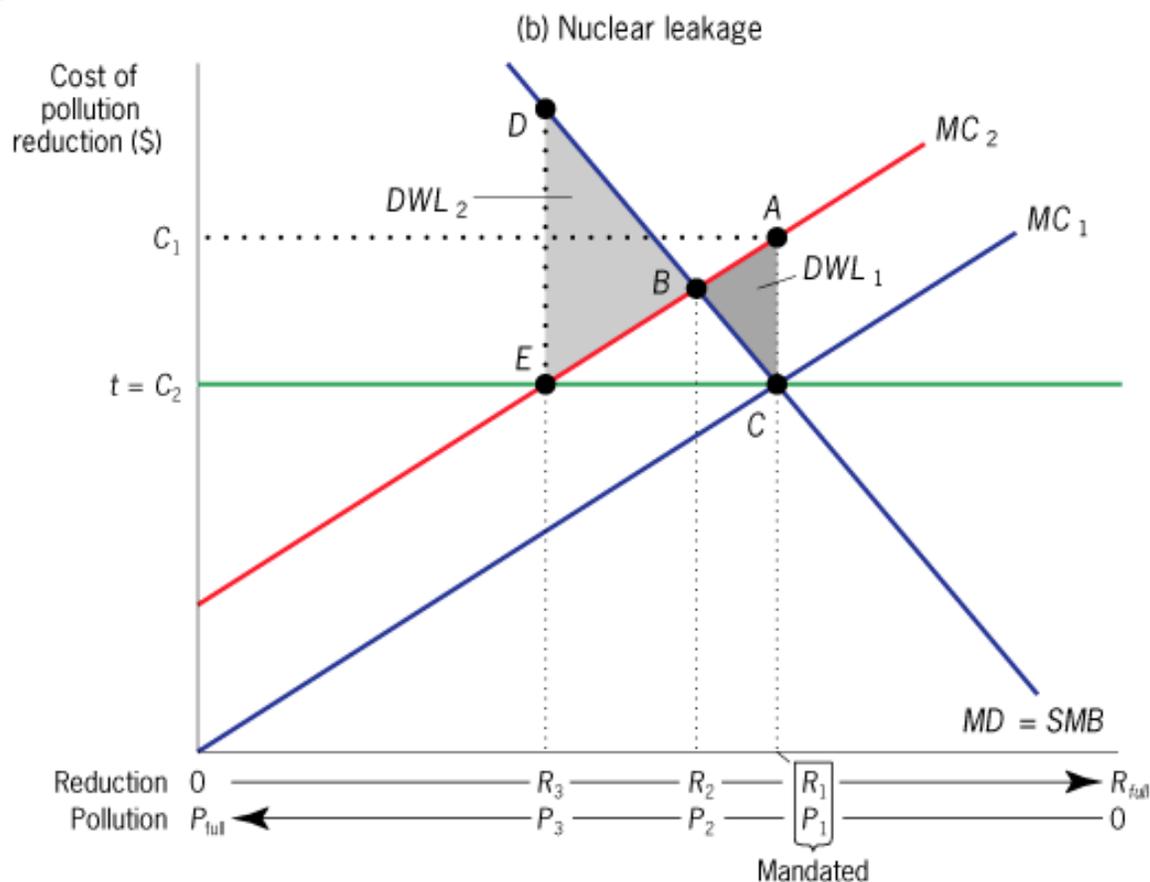
Market for Pollution Reduction with Uncertain Costs • In the case of global warming (panel (a)), the marginal damage is fairly constant over large ranges of emissions (and thus emission reductions). If costs are uncertain, then taxation at level  $t = C_2$  leads to a much lower deadweight loss ( $DBE$ ) than does regulation of  $R_1$  ( $ABC$ ).

## - 5.4 -

# Distinctions Between Price and Quantity Approaches to Addressing Externalities

## Uncertainty About Costs of Reduction

■ FIGURE 5-10b



**Market for Pollution Reduction with Uncertain Costs**

- In the case of nuclear leakage, the marginal damage is very steep. If costs are uncertain, then taxation leads to a much larger deadweight loss ( $DBE$ ) than does regulation ( $ABC$ ).

## CONCLUSION

Externalities are the classic answer to the “when” question of public finance: when one party’s actions affect another party, and the first party doesn’t fully compensate (or get compensated by) the other for this effect, then the market has failed and government intervention is potentially justified.

This naturally leads to the “how” question of public finance. There are two classes of tools in the government’s arsenal for dealing with externalities: price-based measures (taxes and subsidies) and quantity-based measures (regulation).

Which of these methods will lead to the most efficient regulatory outcome depends on factors such as the heterogeneity of the firms being regulated, the flexibility embedded in quantity regulation, and the uncertainty over the costs of externality reduction.