Unit 1: Economic Fundamentals

Econon 3535

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Lecture 1

- Intro to Class
- Prisoner's Dilemma Review

Reading for this class:

Robert Frank's The Darwin Economy

Elk Antlers and the Prisoner's Dilemma

Elk's Prisoner Dilemma

Elk in the wild battle for females with their horn. Having larger horns gives an advantage in battling horns.

Large horns hurt their ability to run away from predators though. If elks could agree, they would all prefer to cut the size of their horns in half.

Payoff Table:

Elk 2 / Elk 1	Big Horns	Small Horns
Big Horns	(3,3)	(8,0)
Small Horns	(0,8)	(5,5)

Elk's Incentives

If Elk 2 is going to have big horns, two options:

- Elk 1 has big Horns, the payoff would be 3.
- Elk 1 has small Horns, the payoff would be 0.

Elk 1 will choose big horns (or, natural selection chooses). We call big horns a *dominant strategy*

The same is true for Elk 2. The Nash Equilibrium is big horns.

Payoff Table:

Elk 2 / Elk 1	Big Horns	Small Horns
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Small Horns	(0,8)	(5,5)

Terminology

Game Theory:

- The study of strategic interaction between rational decision makers

Nash Equilibrium:

- A common outcome in game theory models, where incentives overlap in a way that produces a “rational” solution

Prisoner's Dilemma:

- A type of Nash equilibrium where cooperation leads to the best overall outcome, but individual incentives push away from this outcome

Nash Equilibrum

We have assumed that you have no control over the other person's choice.

Do we believe this to be true in the following games:

- Elk Horns?
- Selling used car and being honest about it's condition? What about selling to your family?
- Two restaurants choosing the price of their meals?

Prisoner's Dilemma in Resource Economics

Open Access Goods:

- *Non-excludable* resource that can be used by anyone.
- What happens to a park on a nice summer day?

Natural Resources

- Different from most other goods because they do not originally belong to anyone

Natural Resources Examples

Cooperation vs. Defection

Oil and gas extraction:

Natural Resources Examples

Cooperation vs. Defection

Oil and gas extraction:

- Cooperation = responsible extraction methods
- Defection = damaging extraction

Groundwater extraction:

Natural Resources Examples

Cooperation vs. Defection

Oil and gas extraction:

- Cooperation = responsible extraction methods
- Defection = damaging extraction

Groundwater extraction:

- Cooperation = limited pumping to keep pumping costs down
- Defection = extracting as much as possible and raising the costs for everyone

Climate change mitigation:

Natural Resources Examples

Cooperation vs. Defection

Oil and gas extraction:

- Cooperation = responsible extraction methods
- Defection = damaging extraction

Groundwater extraction:

- Cooperation = limited pumping to keep pumping costs down
- Defection = extracting as much as possible and raising the costs for everyone

Climate change mitigation:

- Cooperation = adhering to international standards
- Defection = emitting as much as is privately profitable

Fisheries and forestry:

Natural Resources Examples

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- Cooperation = responsible extraction methods
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Climate change mitigation:

- Cooperation = adhering to international standards
- Defection = emitting as much as is privately profitable

Fisheries and forestry:

- Cooperation = sustainable harvest levels
- Defection = unsustainable harvest levels

The point

When resource users defect from the cooperative outcome, total economic value is diminished.

Even though it may be rational for all users to defect

Case Study: commonly owned pastures in England

In the early 1800s, ranchers were allowed to openly graze on commonly owned pastures.

> “Why are the cattle on a common so puny and stunted? Why is the common itself so bare-worn, and cropped so differently from the adjoining inclosures?”
>
> William Forster Lloyd, Oxford University, 1832

Ashton (1997) credits enclosing these pastures to private allotments to helping start the industrial revolution by increasing agriculture productivity to the point where farm workers could move to industry jobs.

Tragedy of the Commons

The Commons:

- Any system where finite resources can be accessed and affected by multiple economic agents with divergent interests
- Original term comes from shared grazing land in the middle of a town

Tragedy of the Commons:

- Open access goods are mismanaged as a result of misaligned private incentives

Contrast this with traditional economic markets

- Selfish behavior and the profit motive often lead to a socially optimal outcome

Solutions

- Folk Theorem: when you repeat the game many times, there's more opportunity to work together
- Elinor Ostrom: mechanisms for commons enforcement
  - Research focused on all of the ways that communities overcome the bad incentives- lots of field work
  - Example: Pasture rotations and irrigation schedules monitored and enforced by the users of the commons without any government regulation
- Privitzation of common goods as in the England example.

Reading for Next Time

- "Static Efficiency", page 20
- "Relating Optimality to Efficiency", page 50
- "Comparing Benefits and Costs Across Time", page 52
- "Choosing the Discount Rate", page 62

Lecture 2

- Economic tools for analyzing natural resource problems
- Discounting and Present Value

Recap

- Private benefits but publicly shared costs → suboptimal economic welfare
  - In natural resource economics, this is outcome is called “tragedy of the commons”
- Solutions to Tragedy of Commons
  - Folk Theorem (improvement from repeated interactions)
  - Horizontal enforcement (Ostrom’s research)
  - Expansion of property rights
  - Contracts
  - Laws and penalties

Intertemporal decision making

When you or the government is deciding whether or not to make investments, they must compare the cost they will pay today to the benefits they make in the future.

How do we compare a dollar today to a dollar tomorrow?

Future Value

If I had \$1000 today, what would the value of that money be next year.

- I could invest and make 7% per year

$$\$1000 \times 1.07 \Rightarrow \$1070$$

The future value of \$1000 today is \$1070 next year.

What about this. If I had \$1070 next year, what would that be worth to me this year?

$$\$1070/1.07 \Rightarrow \$1000$$

\$1070 next year is only worth \$1000 this year.

Discounting

Discount Rate captures the *time value of money*. A dollar today is worth more than a dollar tomorrow.

Why?

1. If I could have the dollar today, I could invest that money and have more than a dollar tomorrow.
    - The government currently uses 7% which means the average capital investment makes 7% year over year.
2. People like stuff today more than tomorrow. This is a subjective component.
    - The government estimates this is about 3%. That is, consumers like $1 of consumption today the same as $1.03 next year.

Council of Economic Advisors Brief on Discounting

Why use Discounting?

People actually think this way, if not precisely

- Banks use discounting to decide interest rates they charge
  - They only give out money to places that will make them returns
- Government agencies use it to decide on spending
  - If future benefits are valued more than the policy cost today, then the government implements the policy
- People use it when making large purchases
  - We tend to be impatient :-)

Present Value

Present value allows us to compare benefits/costs over time (i.e. *intertemporal tradeoffs*)

In words:

- To calculate present value, discount future values back to today.
- Capture what some future outcome (benefit or cost) is equal to in present dollars

In math:

$$PV(B_t) = B_t/(1+r)^t$$

- t: time-index (e.g. years). Today is $t = 0$, next year is $t = 1$, and so on.
- B_t: amount of benefit or cost in period t
- r: discount rate. Many different options for r and require a choice (e.g. $r = 0.03$).

Example

How much would you be willing to pay now for something worth \$1000 in 5 years time.

$$PV(1000) = 1000/(1+r)^5$$

- $r = 0$:
    - $PV(1000) = 1000/(1)^5 =$ \$1000, i.e. the same because you don't discount the future.
- $r = 0.02$:
    - $PV(1000) = 1000/(1.02)^5 =$ \$905.73
- $r = 0.10$:
    - $PV(1000) = 1000/(1.04)^5 =$ \$620.92

Which Discount Rate to Use?

Private decisions:

Market interest rates = Revealed time preference

Policy decisions:

Much debate! (Example 3.4 in our textbook)

- Stern Review used 0.1-1.4% (panic, prescriptive)
- Nordhaus prefers 3-6%, as does IPCC (apathy, descriptive)
- US government uses 2.5%-3.5% (in between)

Lower discount rates $\Longrightarrow$ more value placed on future

Climate Change Example

Let's say climate change will cost $2 trillion dollars 100 years from now (per year).

How much would we invest today to avoid this this cost:

$r = 0.03$:

$$2,000,000,000,000/(1.03)^{100} = 104 \text{ billion}$$

$r = 0.07$:

$$2,000,000,000,000/(1.07)^{100} = 2.3 \text{ billion}$$

Net Present Value Stream

Of course, climate change will create costs for each year, so we will add up all the present value of costs per year:

$$C_1/(1+r)^1 + C_2/(1+r)^2 + \dots + C_{100}/(1+r)^{100} + \dots$$

If we invest today to prevent the damages, this number is the present value of benefits.

We compare that to the investment costs to prevent the damages:

$$I_1/(1+r)^1 + I_2/(1+r)^2 + \dots + I_{100}/(1+r)^{100} + \dots$$

where I is the investment cost of stopping the damages.

Two important considerations:

1. What is the appropriate value of r?

2. Since 2010, the investment cost of stopping climate change has dropped precipitously so the present value of benefits (avoiding climate damages) is getting larger relative to the present value of investment costs to avoid climate damages

Economic Models

> “All models are wrong, but some are useful”
>
> George Box

In our case, “useful” means whether or not the models give a deeper understanding of natural resources

Components of an Economic Model:

- Motivation
- Assumptions
- Agents
- Equilibrium

Reading for Next Time

- "Resource Taxonomy", page 119
- "A Two-Period Model", page 103-107
- Michael Greenstone's Managing Climate Risk (online version).

Lecture 3

- Resource taxonomy
- Recyclable resources
- Two-period model with constant MC and fixed supply

Recap

Benefits and costs that happen in the future need to be compared to those that happen now

- How much should we be willing to invest to avoid 1 million dollars worth of climate change?

Present Value:

$$PV(B_t) = B_t/(1+r)^t$$

- Which discount rate to use is a tough choice and requires thought.

Depletable Resources

Current Reserves (economic)

- Can be profitably extracted at current prices

Potential Reserves (economic)

- Function of prices and costs

Resource Endowment (geographic)

- Total amount of resources in the ground

Example: Gold Mine

https://www.youtube.com/embed/txMhW-K4xnc

- Should this mine be in the Current Reserves or the Potential Reserves?
- If the price of gold dropped by 80%, should this mine be in the Current Reserves or the Potential Reserves?

Recyclable Resources

Manufacturers either buy recycled materials from processing plants, or else source new materials from elsewhere

- Incentives to recycle change with the price of the raw material and the price of recycling material

A subset of potential reserves

- Recyclability of a material is also function of market prices

If all costs are accounted for, this determines "recyclability"

- e.g., Metals and paper are often more recyclable than glass

Modeling Efficient Material Allocation

Motivation:

- As a country, want to decide how much of the mineral is efficient to leave behind

Assumptions:

- Only two time periods, constant MC, simple demand function, etc.

Economic agents:

- Suppliers and buyers in both periods

Equilibrium:

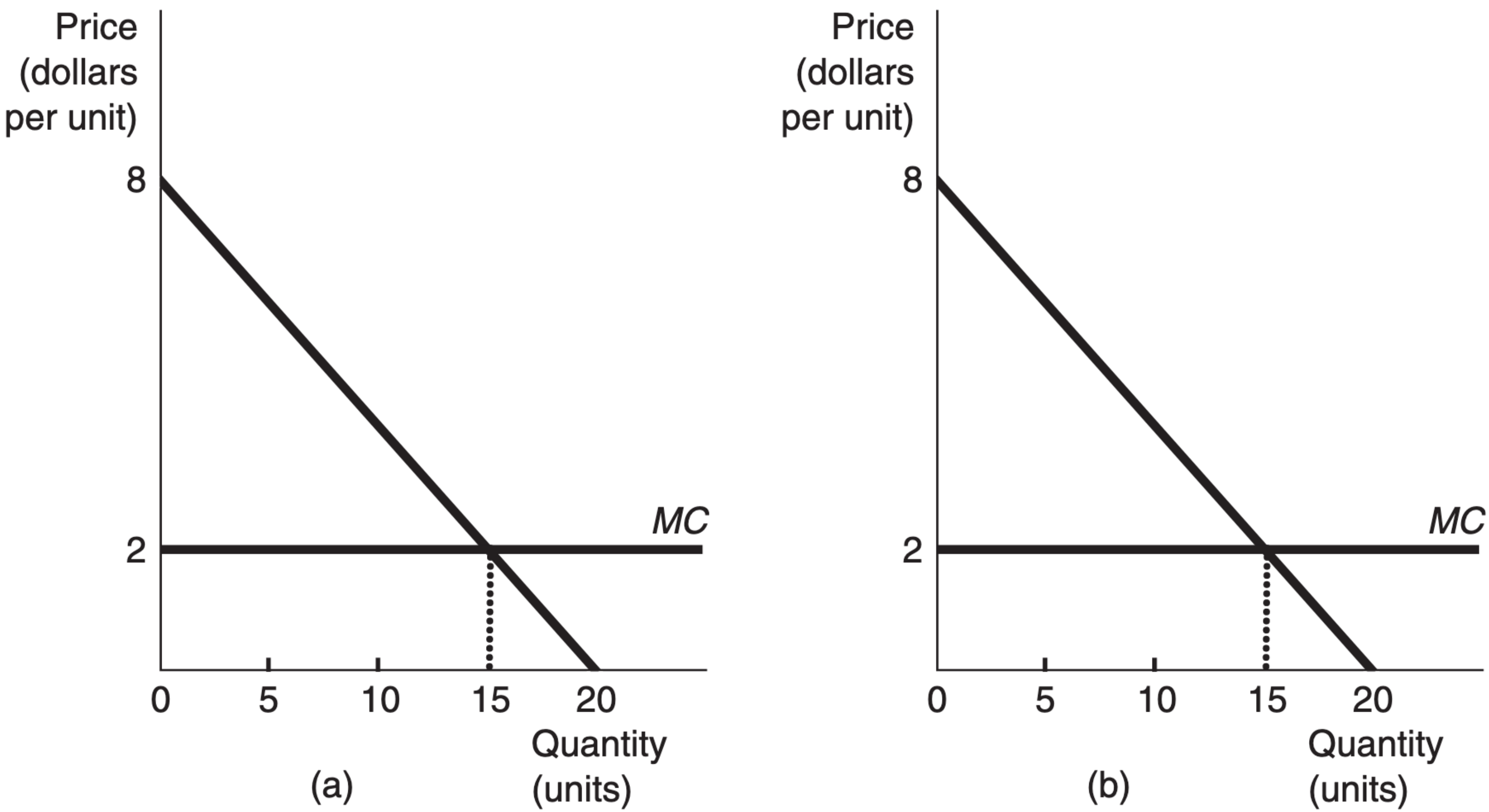
- *Pareto Optimal*: nobody can be made better off without making someone else worse off
- *Dynamic efficiency*: total economic surplus (value created) is maximized across time (taking into account the discount rate)

Mineral Example

Consider a country trying to decide how much gold to extract from their mines today versus tomorrow.

- **Two-Period Model**: now and future
- **Inverse Demand Curve**: $MB = P = 8 - 0.4Q$
  - This tells us the marginal benefit we get from extracting more gold
- **Marginal Cost**: $MC = 2$
  - This tells us how much it costs to extract a unit of gold
- **Supply** is connected to the resource endowment, which is the amount that is theoretically available.
  - Supply matters! Is $S = 20$? $S = 30$?
- **Discount rate**: The country is not very patient, so $r = 10\%$

FIGURE 5.1 The Allocation of an Abundant Depletable Resource: (a) Period 1 and (b) Period 2



Unlimited Supply Example ($S = 30$)

Unlimited Supply Example

When supply is sufficiently large (no scarcity), we keep mining in each period so long as the marginal benefit of mining outweighs the cost of extraction.

$$MB = MC \implies MB = 8 - 0.4Q = 2 = MC$$

Solving for Q yields

$$6 = 0.4Q \implies Q^* = 15$$

The country wants to extract 15 units of gold each period (today and the future).

A different way of writing this is marginal *net* benefits:

$$MNB = MB - MC = 8 - 0.4Q - 2 = 6 - 0.4Q.$$

The country should stop when $MNB = 0$.

Scarce Supply $S = 20$

When there is not enough resources (which is the real world!), there is a fundamental tradeoff:

When I extract resources today, I can not extract them tomorrow

What tool did we learn that helps us compare benefits today vs. benefits tomorrow? Present Value!

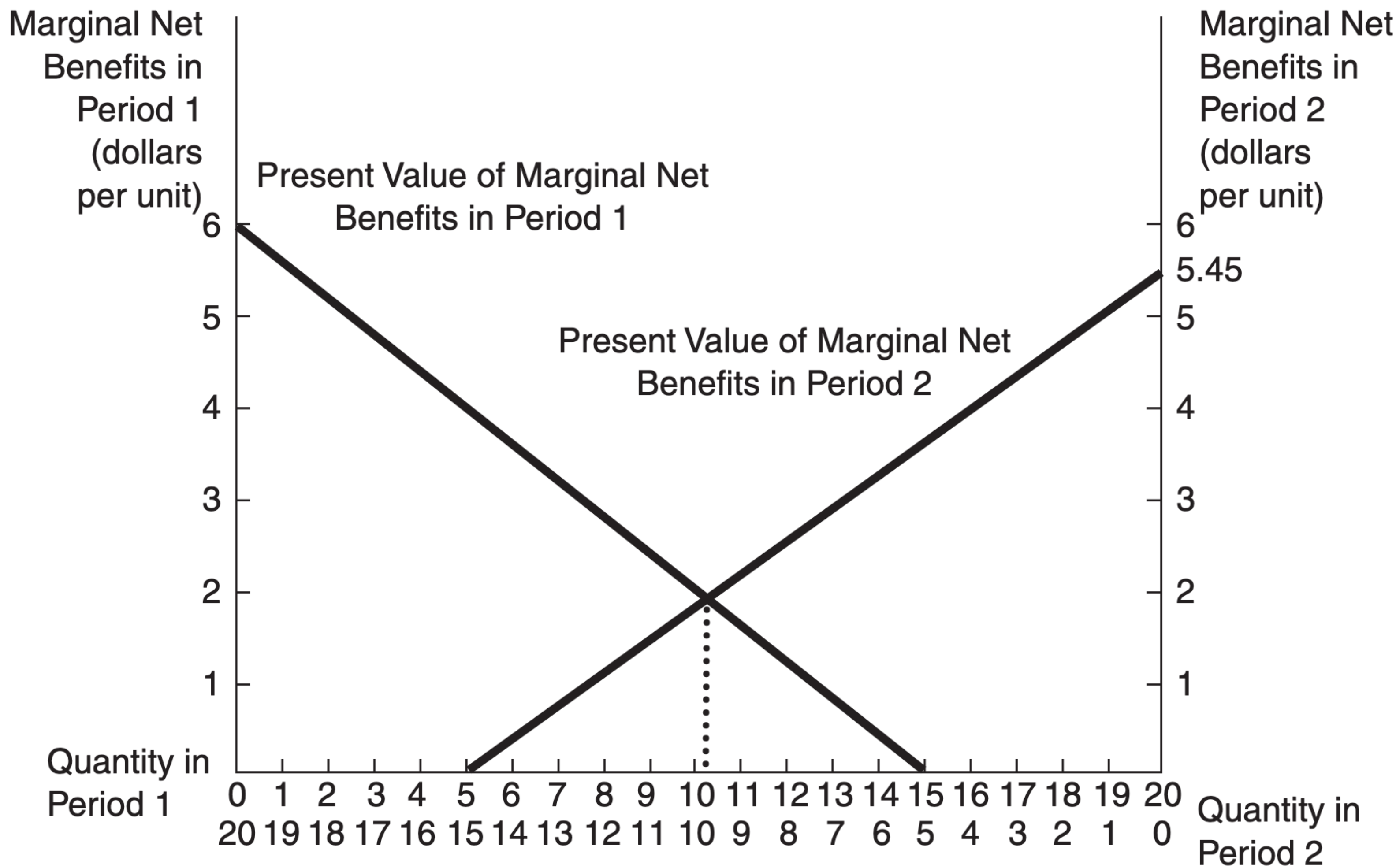
We therefore need to compare MNB in period 1

$$MNB_1 = 6 - 0.4Q_1$$

to the *present value* of MNB in period 2

$$PV(MNB_2) = \frac{6 - 0.4Q_2}{1.1} \approx 5.45 - 0.36Q_2$$

FIGURE 5.2 The Dynamically Efficient Allocation



In the figure, we have three important features:

1. The x-axis has Q_1 and Q_2 and draws them such that $Q_1 + Q_2 = 20$.
    - Whatever they don't extract in period 1, they will extract in period 2 (since optimally they would want to extract 30 units!)
2. As we extract more in either period, the marginal net benefit is declining
    - It becomes more and more attractive to mine in the other period
3. The equilibrium is when $MNB_1 = PV(MNB_2)$ under the constraint $Q_1 + Q_2 = 20$.
    - This is two equations with two unknowns (\$Q_1 + Q_2 = 20\$). Let's put on our algebra hats and solve!

Solving the Model

$$6 - 0.4Q_1 = \frac{6 - 0.4Q_2}{1.1} \text{ and } Q_1 + Q_2 = 20$$

Marginal User Cost

Marginal User Cost:

The present value of these forgone opportunities at the margin.

- Without scarcity, producers will continue to produce until the marginal unit has net benefit of 0.
- With scarcity, producers will produce until they run out of resources. There could be value to having another unit.
  - In particular, if you could extract one more unit in period 1 it would be worth $MNB_1(Q_1^*)$ dollars to you, where Q_1^* is however many units you are currently mining.

This is the Marginal User Cost. $MUC = MNB_1(Q_1^*) = PV(MNB_2(Q_2^*))$, where Q_1^* and Q_2^* are the optimal quantities.

Complicating the Model

Discuss in groups the following scenarios:

Different demand curves across time

- Kerosene vs coal vs natural gas

Evolving marginal cost of extraction

- Bioeconomic systems
- e.g. fish supply grows more slowly if you fish more in period 1

Relationship with complements/substitutes

- Coal vs natural gas

Exploration and technology progress

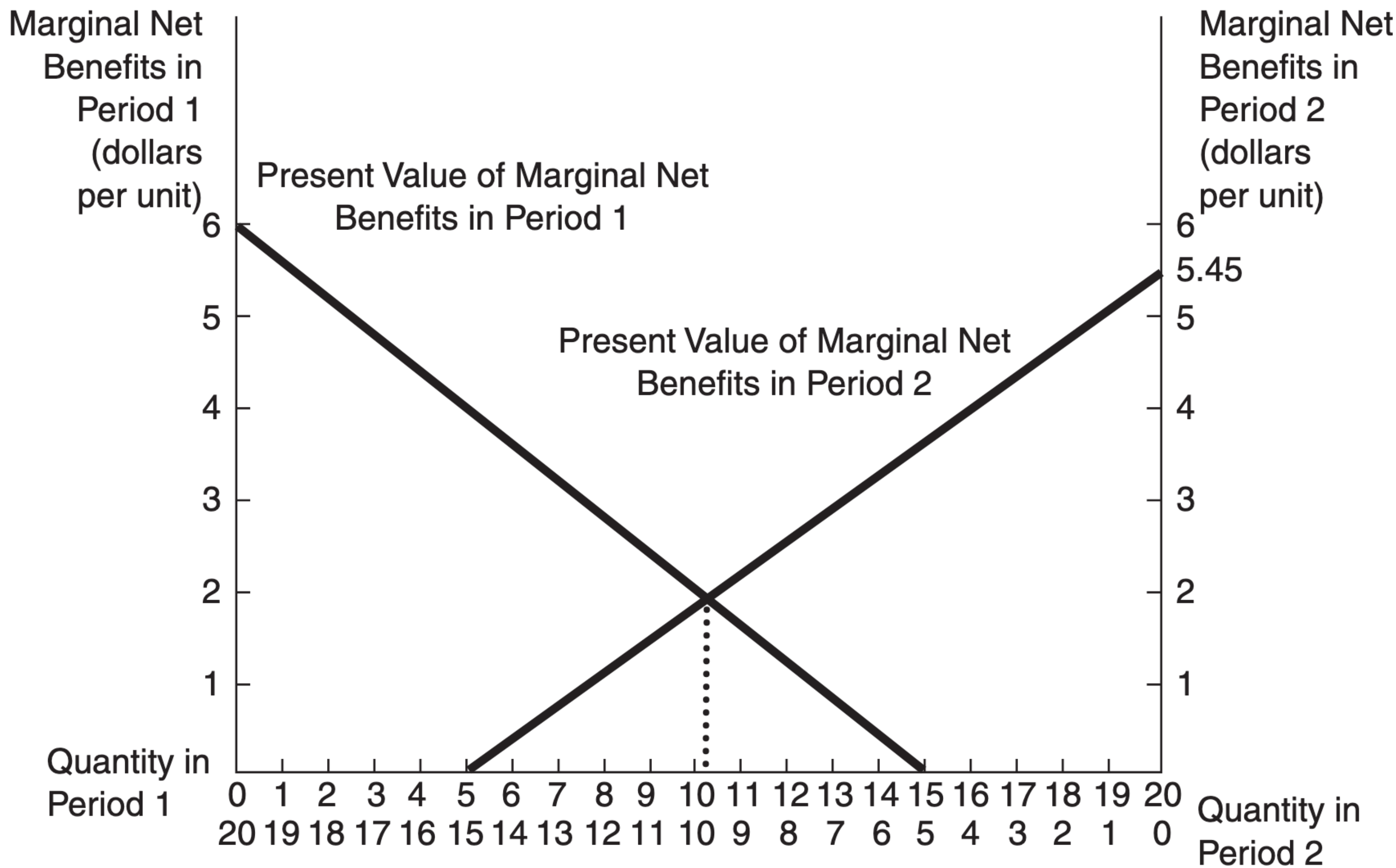
- Fracking

Do Mineral Markets Work?

Since firms are rationally self-interested, markets work as long as:

1. they discount the future the same as society does
2. property rights are secure (no tragedy of the commons issues)
3. all costs are considered (private costs and costs to society)

FIGURE 5.2 The Dynamically Efficient Allocation



Review Questions

- Why do we put the period 2 quantities going in the opposite direction?
- Why are the intercepts (6 vs. 5.45) different?
- What would happen to the intercepts if the discount rate decreased?
- What does the value on the y-axis represent at the equilibrium?

Reading for Next Time

- "Externalities as a Source of Market Failure", page 25-27
- Example 2.2 Shrimp Farming Externalities in Thailand, page 27

Lecture 5

- Efficiency
- Welfare theorem
- Property rights

Macro View of Efficiency

Trade and the environment

- Race to the bottom
- Porter Hypothesis
- Environmental Kuznets Curve

Resources and development

- Natural resource curse
- Institutional quality

Micro View of Efficiency

Efficient operation of markets

- Welfare theorem
- Property rights

Inefficient operation of markets

- Pigou and externalities
- Coase and reciprocity

Correcting inefficiencies with property rights

Efficency

Economic models usually try to find the solution that will provide the best possible outcome

- From among the set of possibilities
- According to the choice of outcome that is being modeled

Examples

- Efficient sustainable yield in a fisheries model
- Efficient harvest date for trees in a forestry model
- Efficient quantity in a supply and demand model

Social Planner

Economists often describe efficiency in terms of what the **social planner** would choose

- Hypothetical, all-knowing, benevolent decision maker who decides everything on behalf of the economic agents
- This outcome contrasts with the outcome resulting from the collective action of many self-interested individuals

Example

In the two-period model with scarcity, (10.3, 9.7) was efficient

However, we would expect (15, 5) is the likely outcome if self-interested users in Period 1 got to make all of the decisions

First Fundamental Welfare Theorem

Provides the conditions needed to be satisfied for the market to reach the same solution as the social planner.

A market allocation will maximize total economic value without need for intervention ***IF*** the following conditions are met:

1. Property rights are well-defined (no externalities)
2. Buyers and sellers behave competitively by maximizing benefits and minimizing costs
3. Buyers and sellers know all prices
4. Transaction costs are zero

Property Rights

A set of legal entitlement over assets are well defined if they are:

1. Comprehensively assigned
2. Exclusive
3. Transferable
4. Secure

Pigou and Externalities

Externality: a cost or benefit imposed on outsiders who had no choice

- Can be modeled as supply or demand externalities (or some of both)
- Named after Arthur C. Pigou (1920)

Examples

- Oil production
  - Negative supply externality: oil spills
  - Negative demand externality: vehicle emissions
- Vaccines
  - Positive demand externality: higher population resilience

Demand and Supply

- Private demand/supply curves consider only value to the decision makers
  - Social demand/supply curves consider society’s value
  - Also called Social MB/Social MC curves
  - "Society" includes buyers/sellers and the rest of the population too
- Difference between demand curve and social MB curve is the per-unit amount of the externality

Market Inefficiency

When an externality is present, the First Fundamental Welfare Theorem is violated because property rights are not well-defined

- Negative externality: you don't have the right to protection from pollution
- Positive externality: you don't have the right to capture benefits of vaccination

Pigouvian Tax/Subsidy

Pigou proposed a corrective tax to deal with negative externalities

Example: If consumption of a gallon of gasoline causes an additional $1 of pollution, put a $1 per gallon tax on it

- Demand curve becomes identical to social MB curve
- Force market participants to internalize the externality
- Benefit: total welfare is maximized
- Drawback: some individuals (who pay the tax) may still lose
    - In theory, can compensate those affected by the externality

Reading for Next Time

- "Externalities as a Source of Market Failure", page 25-27
- Example 2.2 Shrimp Farming Externalities in Thailand, page 27
- "Coase Theorem", page 39-41

Lecture 6

- Coase theorem
- Bargaining

Recap

Externality

- Additional cost or benefit to outsiders

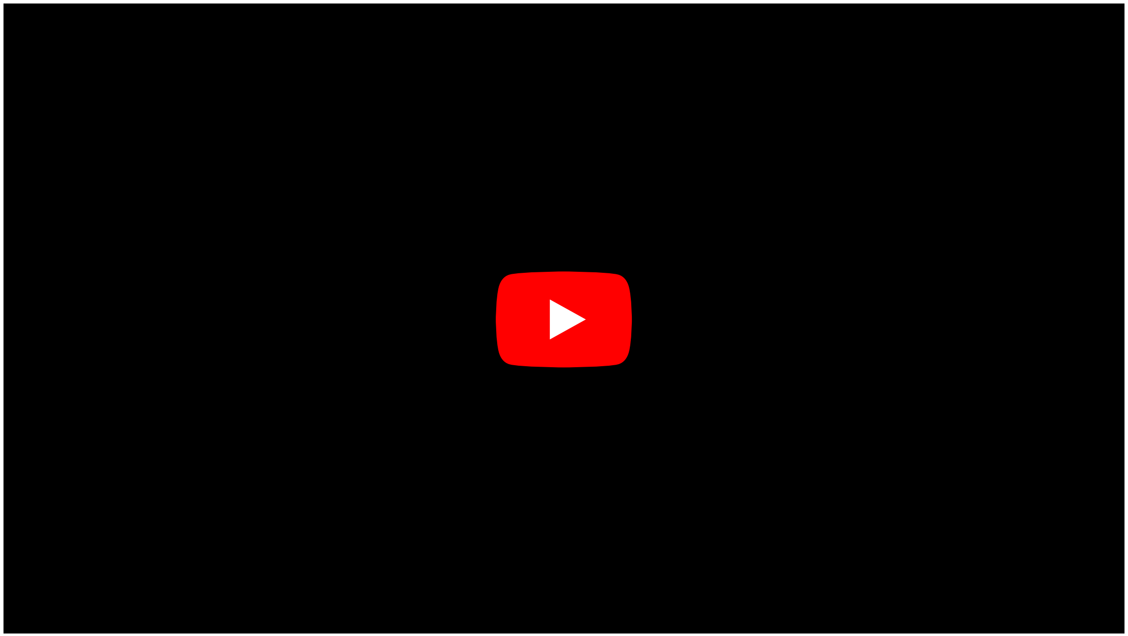
Pigou's solution- taxes and subsidies

- Internalize the externality

First Fundamental Welfare Theorem

- When private decision makers face the same incentives as a "social planner," we get the right outcome

Coase Theorem



https://www.youtube.com/embed/00HPak2RLlQ

Coase Theorem

As long as property rights are secure and transaction costs are zero, both sides can work it out

- Social welfare is maximized, no matter who has the rights
- Ronald Coase (1960)

Maximizing social welfare

- In general, it is at the quantity where social MB = social MC
- When two activities are incompatible, the one with the higher surplus should be allowed

Coase Theorem in Reality

More likely to hold true for bilateral externalities than any other kind

- Two-party negotiations are easier than 10 party negotiations
- Major point of Coase's paper was that transaction costs are *usually too high*

If every human was guaranteed the right to low concentrations of GHGs…

- Fossil fuel companies would have to go door to door negotiating
- Probably would result in a good environment, but also no energy at all

Comparison of Solutions

Suppose a rancher and a farmer operate on adjacent land. The rancher's livestock causes some damage to the farm.

Pigouvian tax

- Assess damage caused per animal, tax the farmer that amount per animal

Coase bargaining

- Assign property rights, let the two sides negotiate (rancher pays the farmer)

Example

Rancher benefits from additional cows

- $MB = 10 – 0.5Q$

Farmer incurs costs from additional cows

- $MC = 0.5Q$

How many cows are socially optimal?

- i.e. how many cows maximum net benefit?

Let’s graph it!

Scenario 1: High Transaction Costs

Whoever has the property rights will enforce them and refuse to negotiate

- Farmer has the rights $\implies$ zero cows
- Rancher has the rights $\implies$ add cows until $MB = 0$

$$10 – 0.5Q = 0 \implies Q = 20 \text{ cows}$$

See the graph to understand why 10 is preferred to 0 or 20

Scenario 2: No Transaction Costs

Coase bargaining can be effective:

Farmer has the rights - negotiate a payment from the rancher for the right to graze

- First cow- rancher is willing to pay up to $9.50, farmer is willing to give up the right for $0.50 or more
- Second cow- rancher is willing to pay up to $9, farmer is willing to give up the right for $1 or more
- ...
- 10th cow- rancher is willing to pay up to $5, farmer is willing to give up the right for $5 or more

Welfare is maximized when Coase Bargaining occurs

Reading for Next Time

- Ronald Coase and the Misuse of Economics (online version).
- "The Command-and-Control Policy Framework", page 397-404

The Big 3: Policy Tools

Command and control

- Standards, technology mandates, quotas, etc.

Taxes (market-based)

- Pricing externalities

Cap and trade (market-based)

- Issue permits, allow for trading

Efficiency of Policy

Assuming we have a clear goal in mind, e.g. emissions

- *Efficiency* is hitting that goal as cheaply as possible

Marginal abatement cost

- The cost associated with eliminating the next amount of pollution
- Different sources (e.g. firms) have different MAC curves
    - E.g. older plants have older technology, so cheap upgrades can go a long way.
    - E.g. it's easier to switch to solar power in sunny California than in rainy Washington

Efficiency means that abatement comes from sources where it is cheapest to abate

Marginal Abatement Cost

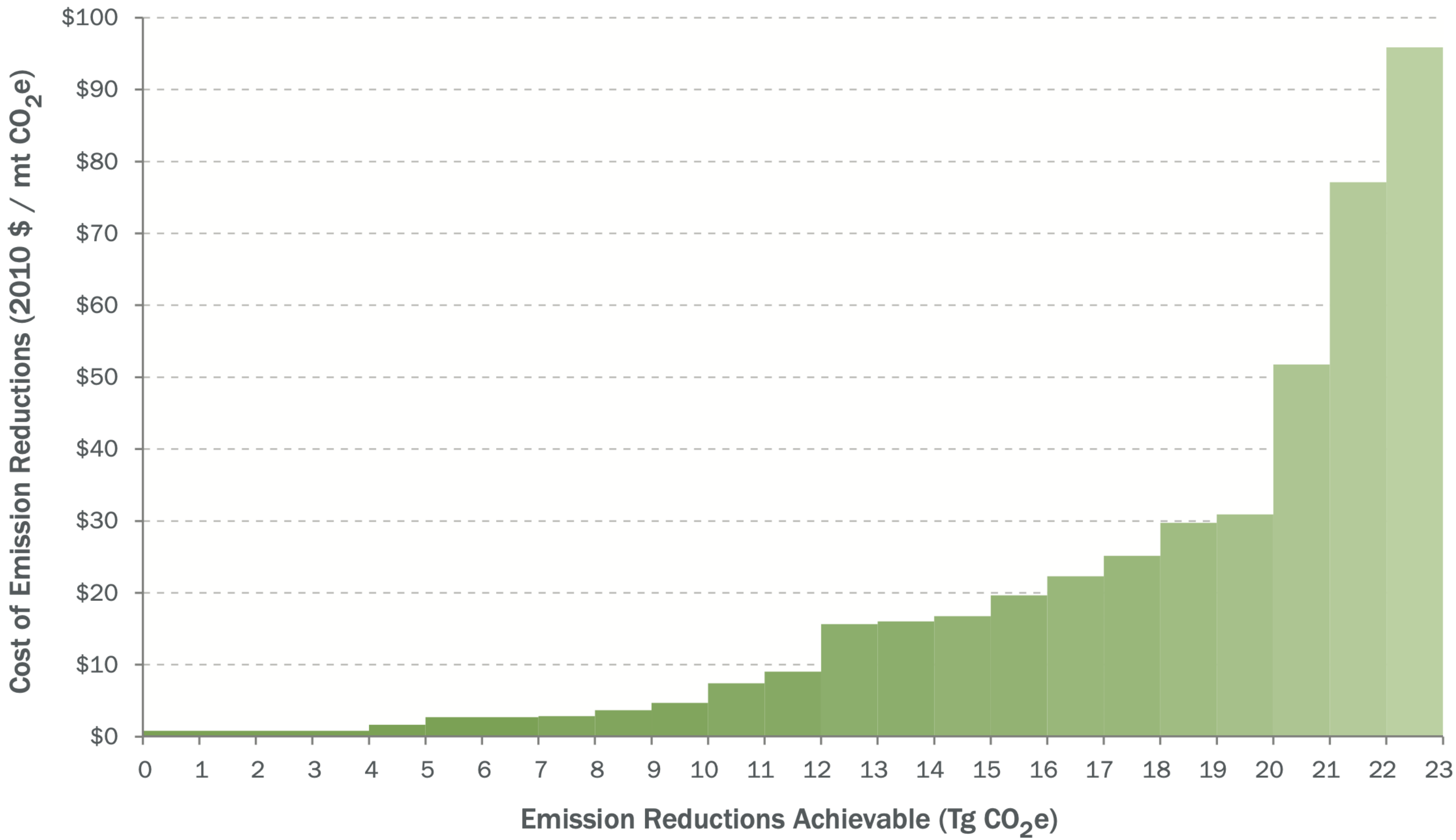
MAC is usually increasing in the level of abatement

- Unconstrained pollution costs nothing to the firm
- First unit of abatement is fairly easy
- For most firms, reducing emissions to zero requires shutting down completely

MAC generally comes from one of two abatement methods (whichever is cheaper)

- Opportunity cost of lowering output/sales
- Direct cost of making the production process cleaner

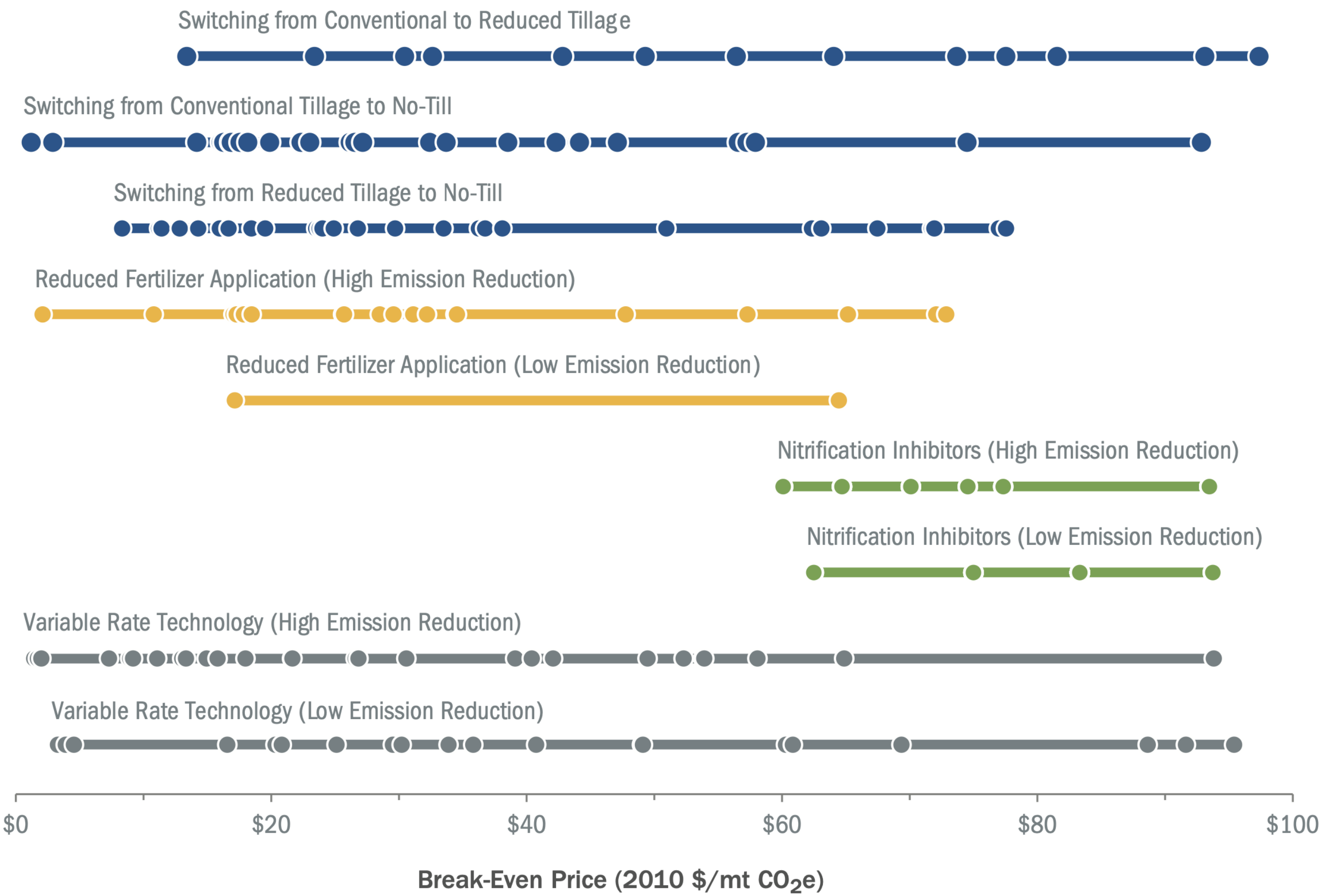
Figure 10: Marginal Abatement Cost Curve for Dairy and Swine Manure Management for CO_2 Break-even Prices of Less Than \$100 per mt CO_2eq



Marginal Abatement Cost Curve Example

USDA Estimates

Figure 11: CO_2 Break-even Prices for Crop Production Systems by Mitigation Option

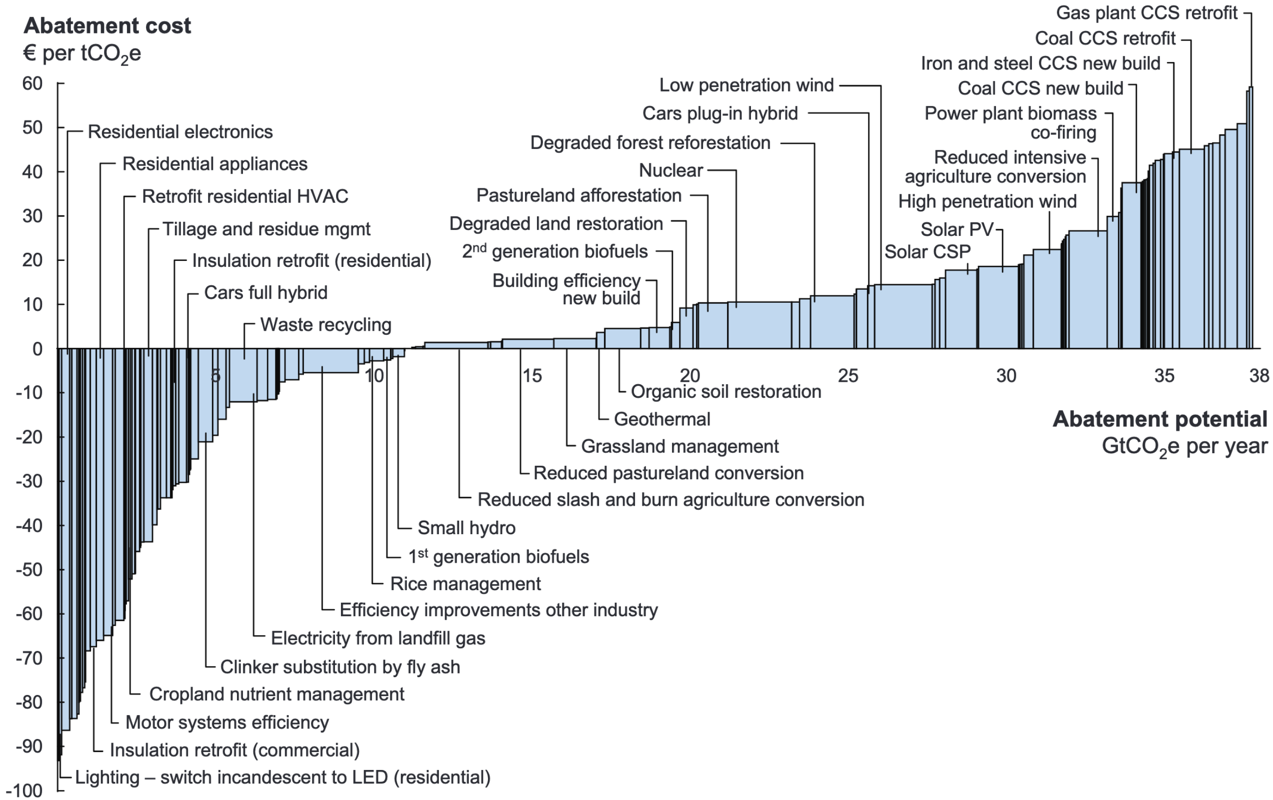


Note: See ICF (2013) for definition of high and low emission reduction (ER) scenarios for reduced fertilizer application and use of nitrification inhibitors and variable rate technology.

Firm Heterogeneity in Costs

Exhibit 1

Global GHG abatement cost curve beyond business-as-usual – 2030



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.0

GHG Marginal Abatement Cost Estimates

McKinsey Estimates

Local Air Pollutants

Important setting where all three major policy tools are used

Local air quality has some of the familiar open-access problems, but not others

- Not hard to measure responsibility for most of it

"Local" means that the emission source matters

- *e.g.* SO2, NOx, fine particulate matter, etc.
- Important non-local emissions include ozone-depleting chemicals and greenhouse gases

National Ambient Air Quality Standar (NAAQS)

Established in the Clean Air Act of 1990, NAAQS sets standards for state and local regulators on six pollutants

- Carbon Monoxide, Lead, Nitrogen Oxides, Ozone, Particulate Matter, Sulfur Dioxide

States can choose which policy tools to use

Pollutant [links to historical tables of NAAQS reviews]		Primary/ Secondary	Averaging Time	Level	Form
Carbon Monoxide (CO)		primary	8 hours	9 ppm	Not to be exceeded more than once per year
			1 hour	35 ppm	
Lead (Pb)		primary and secondary	Rolling 3 month average	0.15 μg/m^3 (1)	Not to be exceeded
Nitrogen Dioxide (NO_2)		primary	1 hour	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		primary and secondary	1 year	53 ppb (2)	Annual Mean
Ozone (O_3)		primary and secondary	8 hours	0.070 ppm (3)	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years
Particle Pollution (PM)	$PM_{2.5}$	primary	1 year	12.0 μg/m^3	annual mean, averaged over 3 years
		secondary	1 year	15.0 μg/m^3	annual mean, averaged over 3 years
		primary and secondary	24 hours	35 μg/m^3	98th percentile, averaged over 3 years
	PM_{10}	primary and secondary	24 hours	150 μg/m^3	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide (SO_2)		primary	1 hour	75 ppb (4)	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
		secondary	3 hours	0.5 ppm	Not to be exceeded more than once per year

Source: epa.gov

Command and Control Policies

Emissions standards

- Assign each polluting firm a level of pollution they are allowed to reach
- Penalize for infractions

Issues

- May prevent high-value production from Firm A (allowance too small)
- May allow low-value pollution from Firm B (allowance too large)

Command and Control Policies

Production/technology standards

- Force all polluting firms to adopt a particular technology or production practice
- Alternatively, ban particularly bad practices

Issues

- Firms may find it less costly to reduce emissions by some other means
- Policy will only be effective to the extent that it mandates the least-cost method of abatement

Corrective (Pigouvian) Taxes

Set a per-unit tax on firm-level emissions

- Increase the MC of production, results in lower equilibrium Q
- Firms still incentivized to maximize profits through optimal production and innovation

Issues

- Sometimes hard to accurately determine correct tax
- Does not act as an emergency backstop

Cap and Trade

Set a maximum level of pollution allowed within a region

- Issue permits that add up to that level, allow firms to buy/sell
- Firms that can cheaply reduce pollution can sell permits to those who cannot

Issues

- Sometimes hard to choose an optimal level of allowable pollution
- Initial permit allocations are often controversial
- But they don't matter for efficiency- Coase Theorem applies!

Reading for Next Time

- "Command and control vs market-based policies", page 397-411

Lecture 9

- Policy comparisons
- Numerical example

Recap

Marginal abatement cost

- Costs faced by a firm of reducing emissions by one more unit

Efficiency requires reducing emissions from the cheapest sources

Cap and Trade and Corrective Taxes both lead to the efficient outcome

- However, the information available to policy makers often means one is preferable to the other

Example

Suppose there are two firms and the government wants to reduce emissions by 15 units (from $40 \to 25$)

Option 1: Command and Control

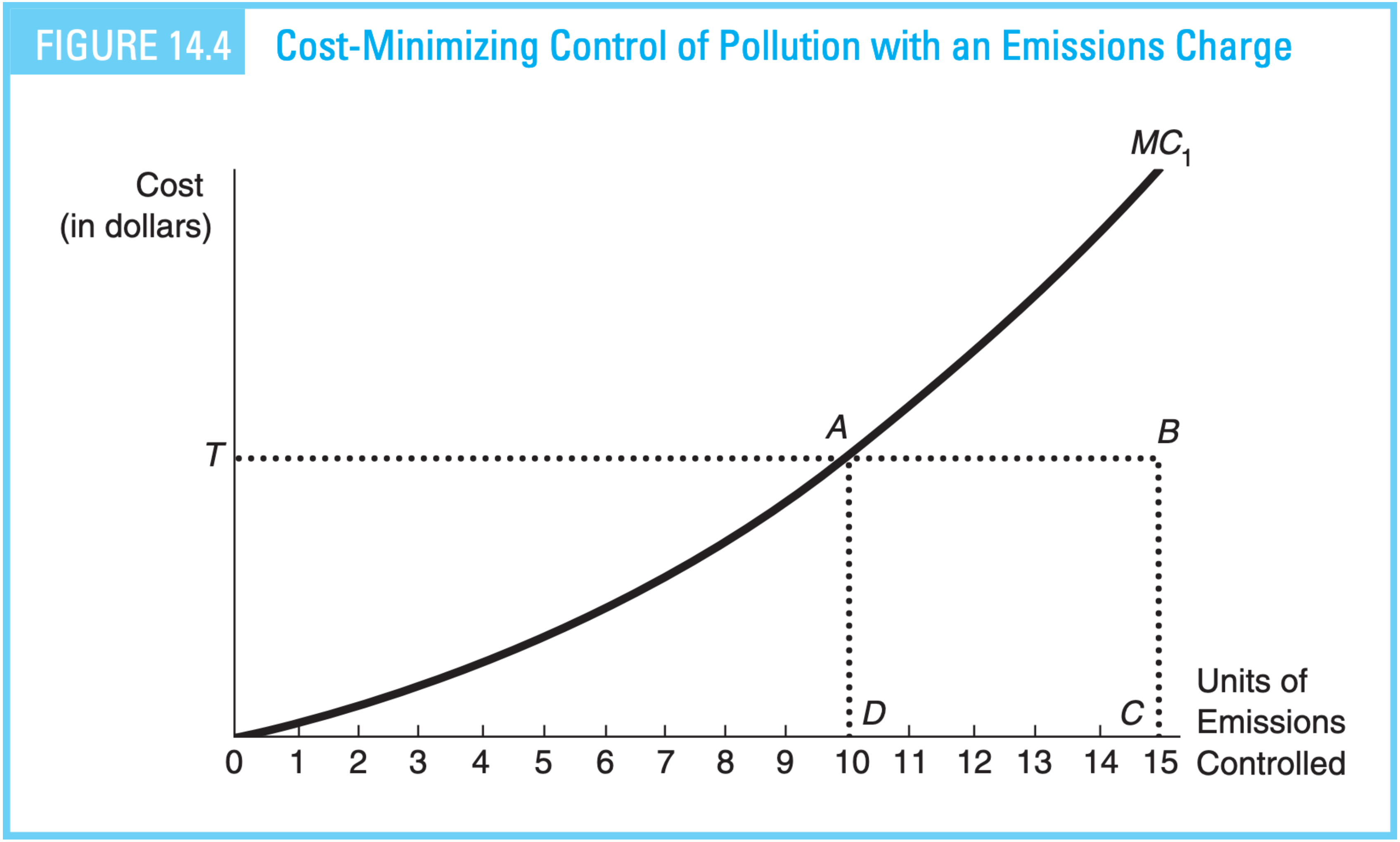
- Choose an abatement amount for each of the two firms, adds up to 15

Option 2: Tax

- Choose a per-unit tax on emissions that incentivizes the two firms to reduce by 15
- Requires knowledge of the full marginal abatement cost curve.

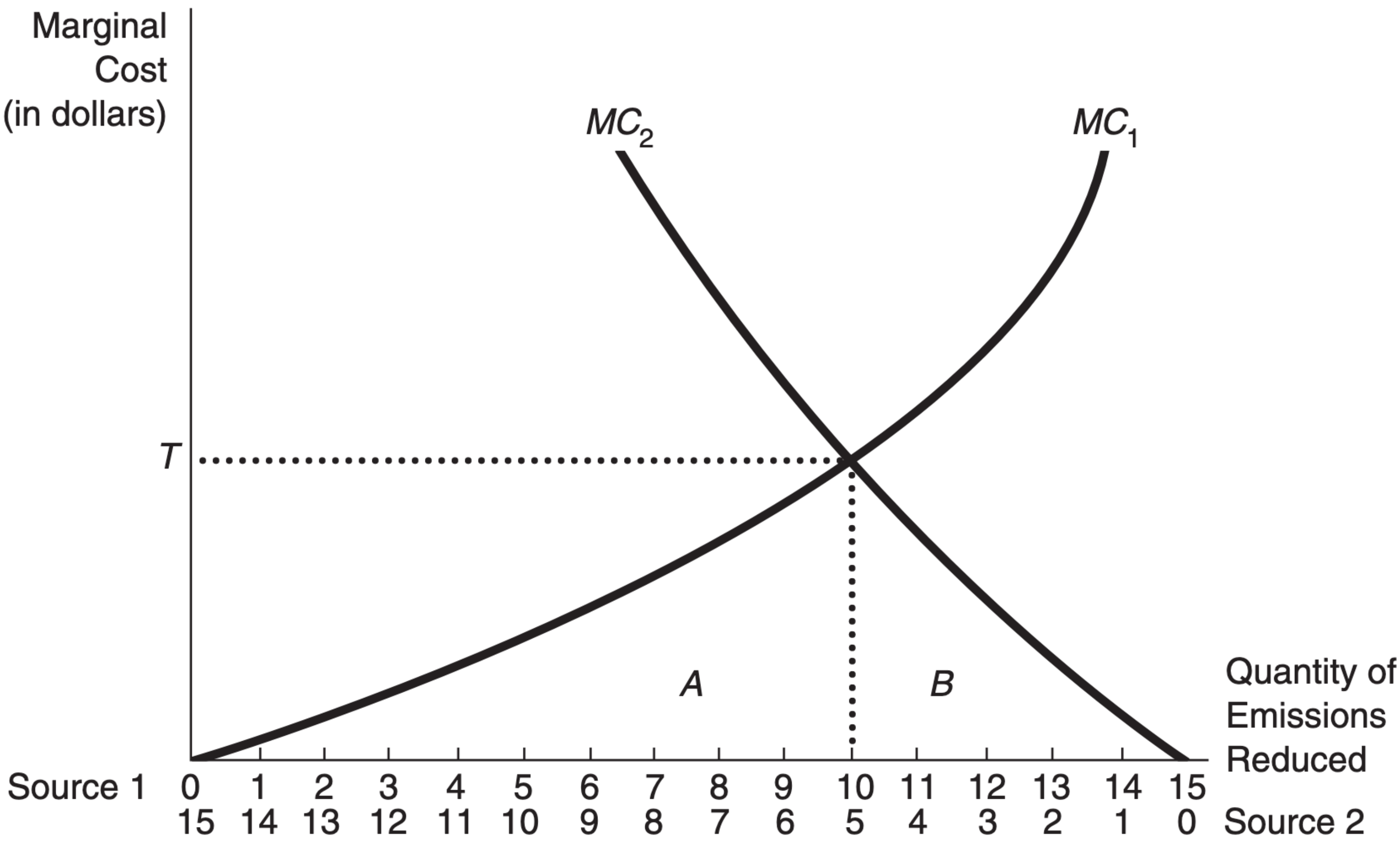
Option 3: Cap and trade

- Issue 25 permits, allow firms to trade as desired



Emission Tax Example

FIGURE 14.3 Cost-Effective Allocation of a Uniformly Mixed Fund Pollutant



Emission Trading Example

Efficiency in the above example

Efficiency is achieved where the MAC curves cross

- Firm 1 reduces by 10, Firm 2 reduces by 5
- If regulation forced it to be (9,6) we would still have 15 units of abatement but at greater total cost to society

A command and control quota will only be efficient if it happens to be exactly (10,5)

Efficiency of Cap and Trade Policy

Suppose the initial allocation of permits cover all but 9 units of Firm 1's pollution, and all but 6 units of Firm 2's pollution

- Firm 2 is willing to pay up to the MAC of the 6th unit for another permit
- Firm 1 is willing to sell a permit for as little as the MAC of its 10th unit

This trade occurs because $MAC_2(6) > MAC_1(10)$.

Therefore we are at an equilibrium (where neither side wants to buy/sell permit) where $MAC_1 = MAC_2$!

Efficiency of Corrective Tax

Optimal corrective tax will be the MAC where the two MAC curves intersect

- Solution was: Firm 1 abates 10, Firm 2 abates 5

Logic behind Firm 1's decision to abate 10 units

- 1st unit's MAC < tax $\implies$ abate this unit
- 2nd unit's MAC < tax $\implies$ abate this unit too
- ...
- 10th unit's MAC = tax $\implies$ indifferent either way
- 11th unit's MAC > tax $\implies$ pay the tax instead of abating

Equivalence of the Two Policies

Under the assumption that the government has *perfect information*...

The optimal tax leading to X units of abatement is the equal to the trading price of permits when X permits are given out

- Cap and trade sets the quantity, taxes set the price

Under both systems, we expect the efficient outcome to occur

- However, perfect information is a very strong assumption, unlikely to hold in reality.
- How would the government know the marginal abatement cost curves of the firms? The firms have no incentive to tell the truth to the government.

Differences between Cap and Trade and Carbon Tax

Government revenue

Suppose that both firms start out polluting 20 units:

Tax

- Pay the tax rate on every unit they do not abate
- Firm 1 pays tax on 20-10 = 10 units
- Firm 2 pays tax on 20-5 = 15 units

Cap and Trade

- Only pay for additional permits beyond the ones provided by government
- Firm who sells permits can actually make money from the policy
- Government can auction permits instead of giving them out for free; can generate some revenue but hard to compare directly with the tax revenue

Videos for Next Class

- How do carbon markets work?
- John Green Explains Cap and Trade

Lecture 10

- Policies Continued
- Numerical Exercise

Recap

Marginal abatement cost

- Costs faced by a firm of reducing emissions by one more unit

Efficiency requires reducing emissions from the cheapest sources

Cap and Trade and Corrective Taxes both lead to the efficient outcome

- However, the information available to policy makers often means one can be preferable to the other

Cap and Trade Model

Government wants to lower sulfur dioxide emissions from the electric power sector, and they have two options:

1. Uniform emissions standard
    - All firms are forced to reduce emissions by a certain amount
2. Cap and trade system
    - Hand out permits, allow firms to trade

Assumptions

- Two firms with different MAC curves
- Firms abate emissions by spending money on pollution control equipment, not by cutting output (simplifying)

Problem Set up

Price of electricity: $100/MWh and both companies supply 1 MWh.

Baseline Emissions: 13 lbs. SO_2 per MWh.

Profit functions are:

$$\pi_x = 100 - 1/2a_x^2$$

$$\pi_y = 100 - a_y^2$$

where a_x and a_y are the amount of emissions abated (lbs. SO_2). Therefore the marginal cost of abatement are:

$$MAC_x = a_x \text{ and } MAC_y = 2a_y$$

Emission Goal: 14 lbs. Remaining 12 lbs. Abated

Questions

For 1. a uniform standard 2. a tradable permit system, find:

- Abatement of each firm
- Total abatement costs for each firm
- Total profit

How does the efficiency of the two policies compare?

- Efficient policy will minimize total abatement costs while meeting the emissions target

Uniform Standard

- $a_x^* = a_y^* = 6$
- This means the $TAC_x = \frac{1}{2}a_x^2 = 18$ and $TAC_y = a_y^2 = 36$. Summing together gives $TAC = 54$.
- Total profit is given by summing individual profits

$$\Pi = 100 - \frac{1}{2}a_x^2 + 100 - a_y^2 = 146$$

Cap and Trade

- To solve for optimal abatement, we will use $MAC_x = MAC_y \implies a_x = 2a_y$ and the abatement goal $a_x + a_y = 12$. Rewriting $a_x = 12 - a_y$ yields:

$$ (12 - a_y) = 2 a_y \implies a_y^ = 4 \text{ and } a_x^ = 8 $$

- This means the $TAC_x = 1/2a_x^2 = 32$ and $TAC_y = a_y^2 = 16$. Summing together gives $TAC = 48$.

- Total profit is given by summing individual profits

$$\Pi = 100 - 1/2a_x^2 + 100 - a_y^2 = 152$$

- Note that costs are lower and profits are higher under cap and trade relative to uniform standard

- This is because the lower abatement cost firm abates more!

- This came at the cost of firm y who has to now abate 8 units instead of 6.

Command and Control in Practice

Economists often argue against command and control policies, especially when affected firms have heterogeneous cost structures

- Fines tend to be too small relative to the cost of compliance
- Incentive to cheat

Benefits of Command and Control

Emergency backstop

- When we know for sure that benefits don't justify a certain level of pollution, a pollution quota doesn't risk inefficiency
- Additional quota mandating each firm to stay below 20 lbs of pollution will not hurt anything

Simple minimum standards

- Banning lead-based paint, for instance
- Phasing out incandescent bulbs?

Regional standards (as in NAAQS)

- Distributes regulatory burden to a lower level than federal

Videos for Next Class

- Taxes and Deadweight Loss
- Pigouvian Taxes

Lecture 11

- Taxes and Deadweight Loss
- Corrective Taxes and Subsidies

Taxes

We saw before how a tax relates to a two-firm cap and trade model

A different way to think about tax is with the supply and demand model

- Often, there are more than two firms producing an externality
- Also, sometimes the demand side produces externalities

Any number of firms can be combined into a supply curve

- The supply curve expresses the number of units the whole market is willing to supply at each price
- Same idea for consumers and the demand curve

Corrective taxes

Tax a market if…

- Social marginal benefit < private marginal benefit, OR
- Social marginal cost > private marginal cost

A tax/subsidy on one side of the market shifts the corresponding curve to the left or right

- Key is to think about effect on incentives

Taxes reduce the quantity of the good bought/sold in the market

- The tax "corrects" incentives that led to too much of the good

Subsidies increase the quantity of the good bought/sold in the market

Example

Tax on supply $\implies$ firms marginal cost increases (supply curve move up)

Tax on demand $\implies$ consumers willing to pay (after the tax) decreases (demand curve shifts down)

Deadweight Loss

Deadweight loss (DWL) is what we call lost potential economic surplus

Always a comparison of two alternative scenarios

- DWL = (old surplus) – (new surplus)

Example: DWL from a tax on movie tickets.

50% tax on movie tickets $\implies$ I will go to the movies less

- Producer surplus: theater loses surplus in the form of profits
- Consumer surplus: I lose surplus because I am no longer buying something that was more valuable to me than the firm's cost
- Government revenue: government gains revenue from the tax

$$DWL = PS + CS - GR$$

Deadeweight Loss Visualized

Before Tax

After Tax

Taxes and Externalities

Regular markets do not generate externalities

- Movie ticket sales don't really affect non-participants

Taxes in regular markets cause DWL because Q is *inefficiently low* after

- There would be greater total surplus if the tax were removed

In markets with a negative externality (and without a corrective tax), there is DWL because Q is inefficiently high

- There would be greater total surplus if the decision makers considered all costs to society, not just their own

Supply-Side Externality and Deadweight Loss

Before Tax

After Tax

Pigovian Tax

Pigou's idea:

- Negative externality can be fixed by an equally sized corrective tax

If the tax is chosen correctly, it will shift the demand curve so that it is the same as the social marginal benefit curve (or supply/ social marginal cost)

The punchline

- We wish people made decisions like the social planner would
- Taxes and subsidies can make up the difference

Reading for Next Time

- "Trade and the Environment", page 545-549
- Example 20.2 The Natural Resource Curse
- Carbon Taxes Won't Do Enough to Slow Global Warming (online version).

Lecture 12

- Growth and Development
- Trade

Midterm

About half and half multiple choice and math/short answer

- Multiple choice based on everything
- Math/Short Answer based on the models covered in the math assignment
  - Be neat, show your work, partial credit is available

The exam is 50 minutes long.

You may bring a "cheat sheet" on a single note card

Midterm test advice

I care about concepts more than situation-specific details

- Good question: Describe in which situations a prisoner's dilemma is able to be "overcame", that is when can people move from Nash Equilibrium to a better outcome?
- Bad question: Which six pollutants are covered under the NAAQS?

Cheat sheet

- In my experience, 90% of the value of a cheat sheet comes from making it
- Personally, I would put theorems and math examples on it, along with concepts I might accidentally mix up with others

International trade

Near-universal agreement from top economists that free trade creates economic value

“If that's not right, almost all of economics is wrong.”

- Richard Schmalensee, in response to this question

Free Trade Question

Race to the Bottom - Pollution havens

- Theory that countries will lower their environmental standards to stay competitive with countries that are willing to pollute
- Prisoner's dilemma again!

Little evidence this has been happening; still a concern for future policies

- Environment is becoming more fragile

Porter Hypothesis

Firms in countries with strict environmental standards may have a long-run advantage

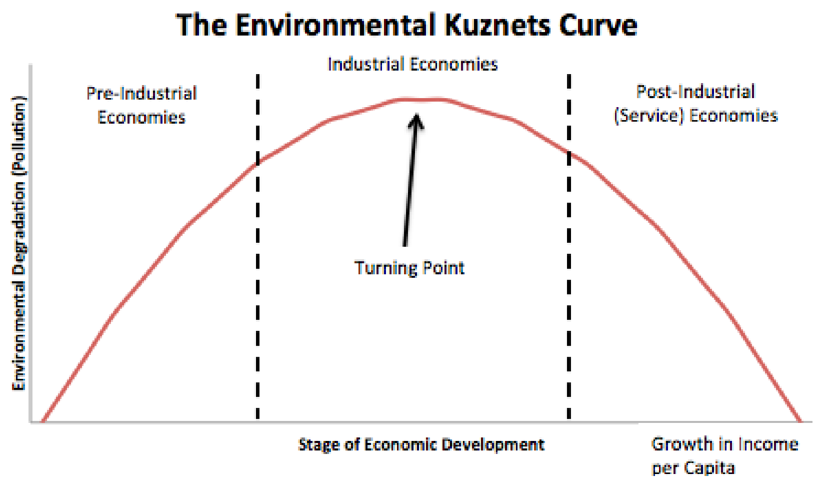
- *Induced innovation* - technology improvements that result from regulations

If this hypothesis is true, trade may cause the opposite of the “race to the bottom”

- Some empirical support, but definitely controversial still
- Might explain lack of support for the race to the bottom theory

Environmental Kuznets Curve

Observed relationship between national income levels and environmental quality measures



Kuznets Curve

Environmental Kuznets Curve

Implications for trade

- If trade makes countries wealthier, maybe makes environment worse
- *Example:* China ($7,000 GDP per capita) exports manufactured goods to the US ($53,000 GDP per capita), resulting in poor air quality in many Chinese cities
- When does a nation start trading off economic growth for environmental quality?

Resource Curse

Natural resources are a valuable component of a nation's economy

However, countries with abundant resource endowments seem to do worse

- Slower economic growth
- More authoritarian governments
- Currency problems

Resources and government

Natural resources are an easy source of revenue

- Little pressure on governments to be accountable
- Well-connected individuals preserve the status quo
- Military regimes can support themselves through conquest

> “There are twenty-three countries in the world that derive at least 60 percent of their exports from oil and gas and not a single one is a real democracy"
>
> - Larry Diamond

Evidence

> “Economies with a high ratio of natural resource exports to GDP… tended to have low growth rates during the subsequent period”
>
> - Warner and Sachs (1995)
>
> “More natural resources push aggregate income down when institutions are grabber friendly” “More resources raise income when institutions are producer friendly”
>
> -Mehlum et al. (2006)

Institutional quality

Mehlum et al. (2006) describe “institutional quality” as an average of five indices

1. Rule of law index
2. Bureaucratic quality index
3. Corruption in government index
4. Risk of expropriation index
5. Government repudiation of contracts index

When economists say that “institutions matter,” this is what they mean