5. ENVIRONMENTAL ECONOMICS

By Vance Ginn

"In the last 100 years, America's population has tripled. Life expectancy has increased 70 percent. The productivity of the American people, measured in terms of real per-capita Gross Domestic Product (GDP) has increased by 600 percent. At the same time, we have consumed more than 340 billion barrels of oil, almost 60 billion short tons of coal and more than 1,090 trillion cubic feet of natural gas."

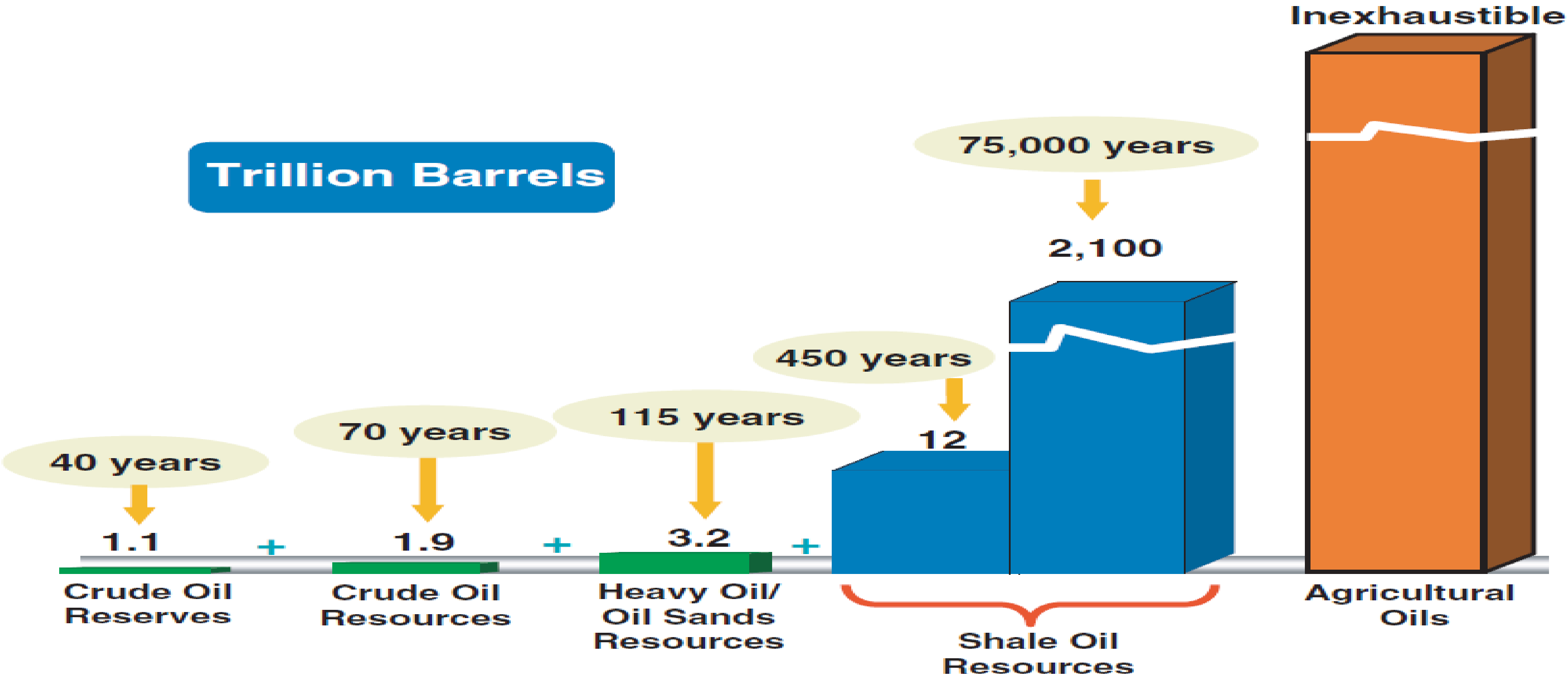
"These things are linked. Affordable and reliable energy is a crucial factor in making these and many other significant human, social and technological achievements possible."

--- Rob Bradley, President, Institute for Energy Research

Will We Run Out of Oil?

Estimated Global Oil Supplies

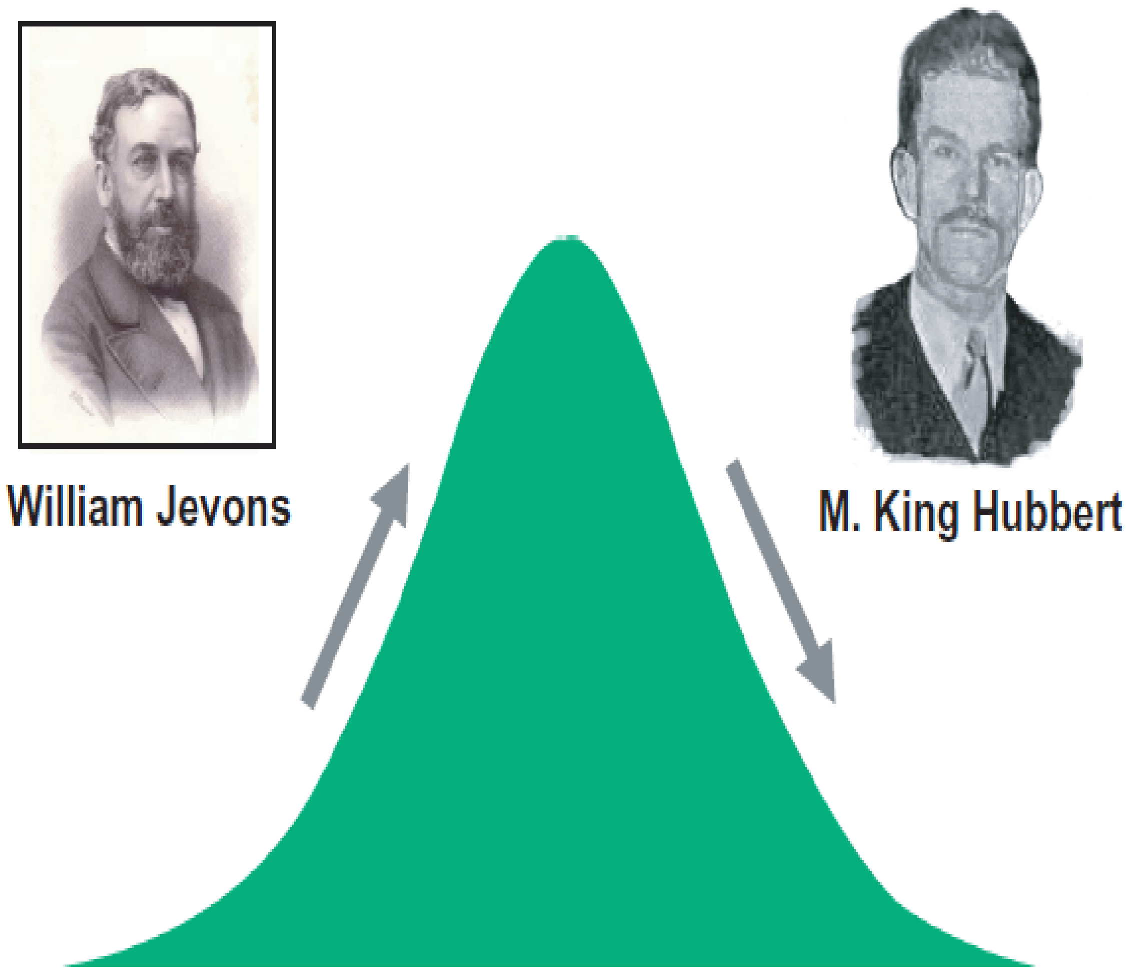
At year-2000 consumption rates, the world has many thousands of years of crude oil and crude oil substitutes (heavy oil, oil sands, and oil shale) remaining. These figures do not even take into account other carbon-based fuels such as coal and natural gas. Note that reserves in this context means proved reserves, and resources means probable future reserves. *Source:* U.S. Energy Information Administration *International Energy Outlook 2002,* p. 32, and the U.S. Energy Information Administration *International Energy Outlook 2001,* p. 47.



Will We Run Out of Oil? Yes…

Energy Depletionists

The traditional view of natural resource production, first formulated in the 1860s by English economist William Stanley Jevons and almost a century later by geologist M. King Hubbert, is that energy production will follow a bell curve—rising, peaking, and declining as reserves deplete.



EXAMPLE 7.1

Hubbert's Peak

When can we expect to run out of oil? It's a simple question with a complex answer. In 1956 geophysicist M. King Hubbert, then working at the Shell research lab in Houston, predicted that U.S. oil production would reach its peak in the early 1970s. Though Hubbert's analysis failed to win much acceptance from experts either in the oil industry or among academics, his prediction came true in the early 1970s. With some modifications, this methodology has since been used to predict the timing of a downturn in global annual oil production as well as when we might run out of oil.

These forecasts and the methods that underlie them are controversial, in part because they ignore such obvious economic factors as prices. The Hubbert model assumes that the annual rate of production follows a bell-shaped curve, regardless of what is happening in oil markets; oil prices don't matter. It seems reasonable to believe, however, that by affecting the incentive to explore new sources and to bring them into production, prices should affect the shape of the production curve.

How much difference would incorporating prices make? Pesaran and Samiei (1995) find, as expected, that modifying the model to include price effects causes the estimated ultimate resource recovery to be larger than implied by the basic Hubbert model. Moreover, a study by Kaufman and Cleveland (2001) finds that forecasting with a Hubbert-type model is fraught with peril.

EXAMPLE 7.1 (cont.)

. . . production in the lower 48 states stabilizes in the late 1970's and early 1980's, which contradicts the steady decline forecast by the Hubbert model. Our results indicate that Hubbert was able to predict the peak in US production accurately because real oil prices, average real cost of production, and [government decisions] co-evolved in a way that traced what appears to be a symmetric bell-shaped curve for production over time. A different evolutionary path for any of these variables could have produced a pattern of production that is significantly different from a bell-shaped curve and production may not have peaked in 1970. In effect, Hubbert got lucky. [p. 46]

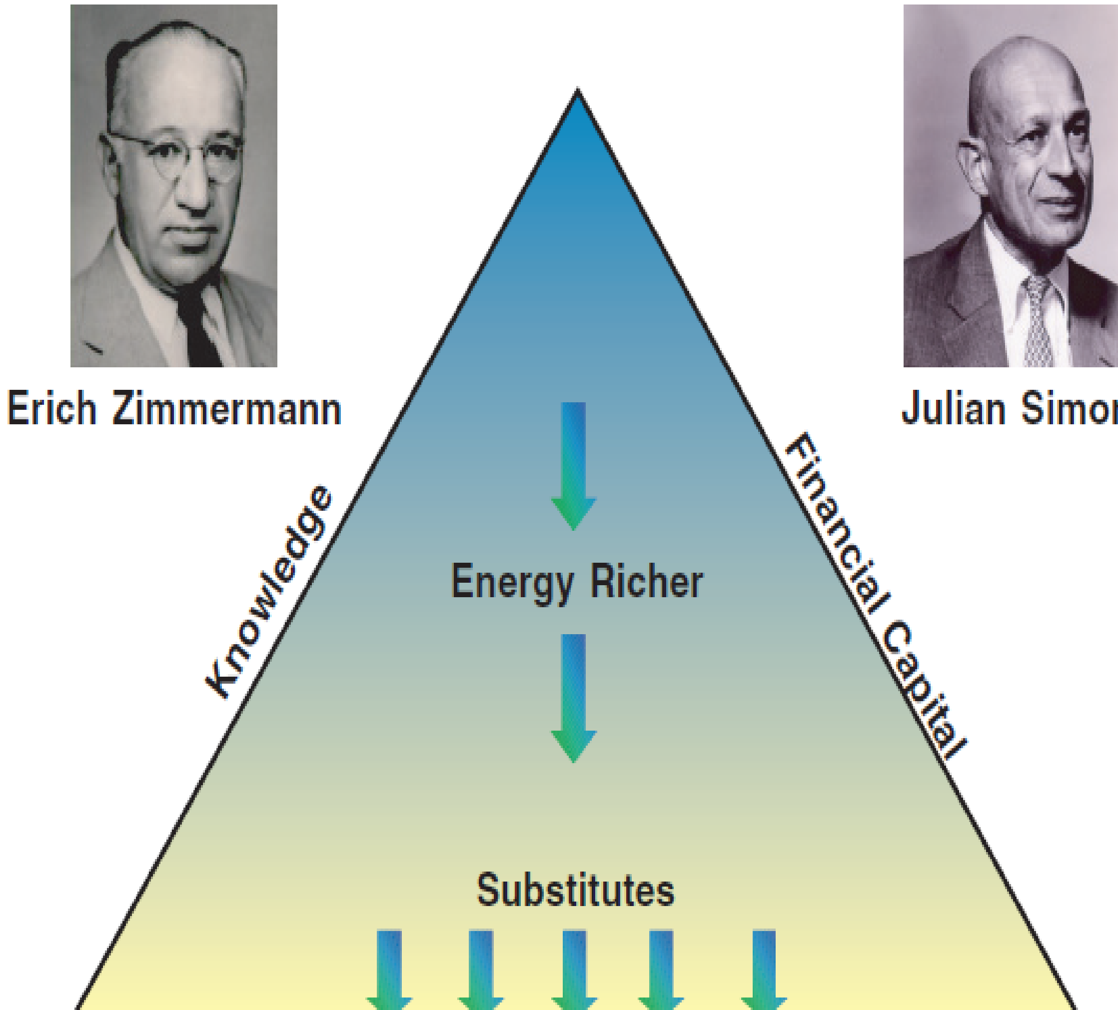
Does this mean we are not running out of oil? No. It simply means we have to be cautious when interpreting forecasts of the timing of the transition to other sources of energy. In 2005, the Administrator of the U.S. Energy Information Agency (EIA) presented a compendium of 36 studies of global oil production and all but one forecasted a production peak. The EIA's own estimates of the timing range from 2031 to 2068 (Caruso, 2005). The issue, it seems, is no longer whether oil production will peak, but when.

Sources: M. Pesaran and H. Samiei, "Forecasting Ultimate Resource Recovery." INTERNATIONAL JOURNAL OF FORECASTING, Vol. 11, No. 4 (1995), pp. 543–555; R. Kaufman and C. Cleveland, "Oil Production in the Lower 48 States: Economic, Geological, and Institutional Determinants." ENERGY JOURNAL, Vol. 22, No. 1 (2001), pp. 27–49; and G. Caruso, "When Will World Oil Production Peak?" A presentation at the 10th Annual Asia Oil and Gas Conference in Kuala Lumpur, Malaysia, June 13, 2005.

Will We Run Out of Oil? No…

ENERGY EXPANSIONISTS

Optimists like Erich Zimmermann and Julian Simon reject the pessimist's bell curve. Instead, they see an *energy pyramid*—expanding energy production as people use knowledge and capital to develop existing resources and discover new ones. Portrait of Erich Zimmermann courtesy of Center for American History, UT-Austin. Portrait of Julian Simon courtesy of Rita Simon.



What is the External Cost of Energy?

- One of the economic principles:

  Markets are usually a good way to organize economy activity.

  In absence of market failures, the competitive market outcome is efficient, maximizes total surplus.

- One type of market failure:

  ______________________: the uncompensated impact of one person's actions on the well-being of a bystander.

- Externalities can be ________________________________, depending on whether impact on bystander is adverse or beneficial.

Government Intervention?

- Self-interested buyers and sellers neglect the external costs or benefits of their actions, so the market outcome is not efficient.

- Another economic principle:

  ____

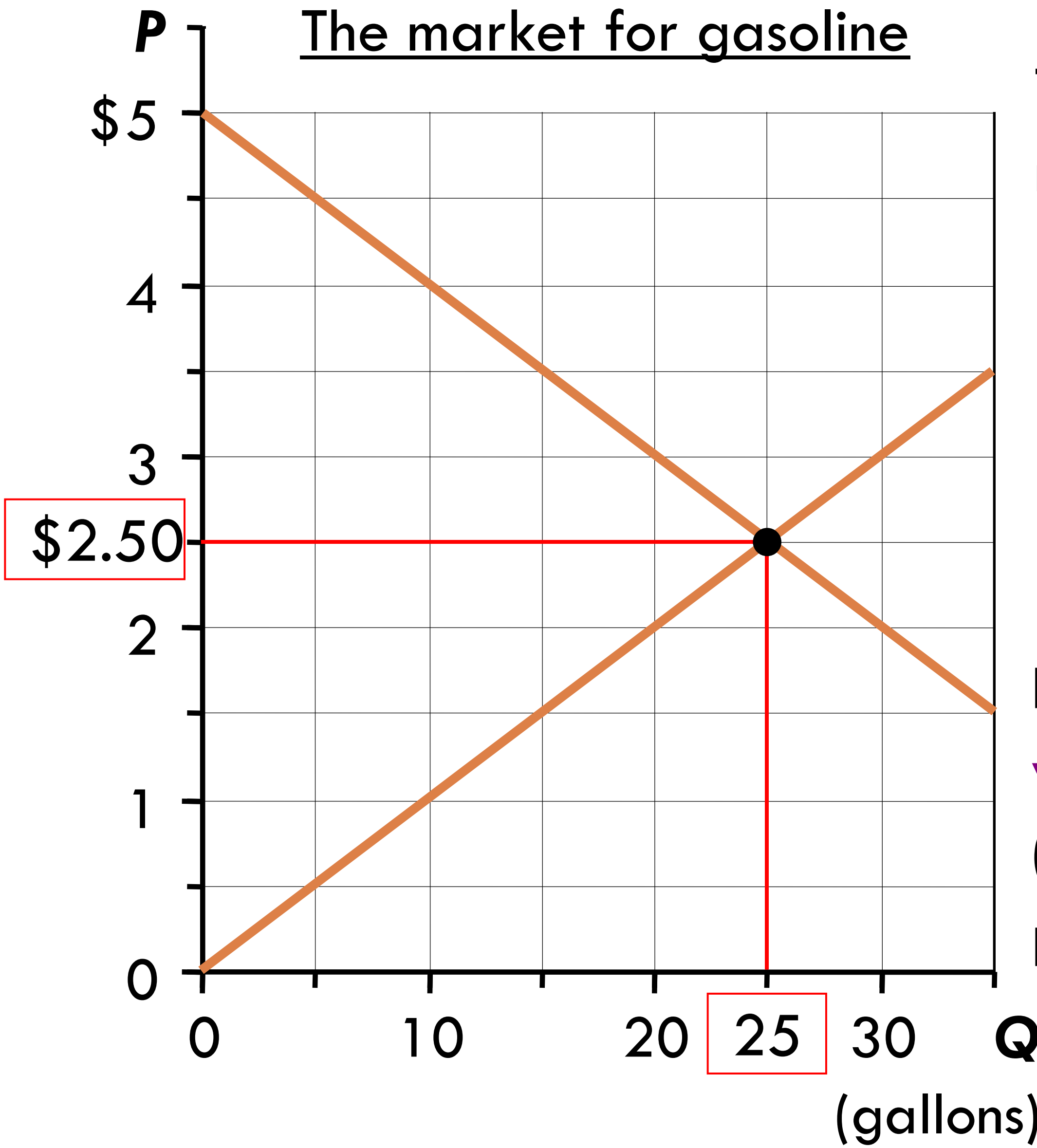
  ____

- In presence of externalities, public policy may be able to improve efficiency.

Examples of Negative Externalities

- Air pollution from a factory
- The neighbor's barking dog
- Late-night stereo blasting from the dorm room next to yours
- Noise pollution from construction projects
- Health risk to others from second-hand smoke
- Talking on cell phone while driving makes the roads less safe for others

Recap of Welfare Economics

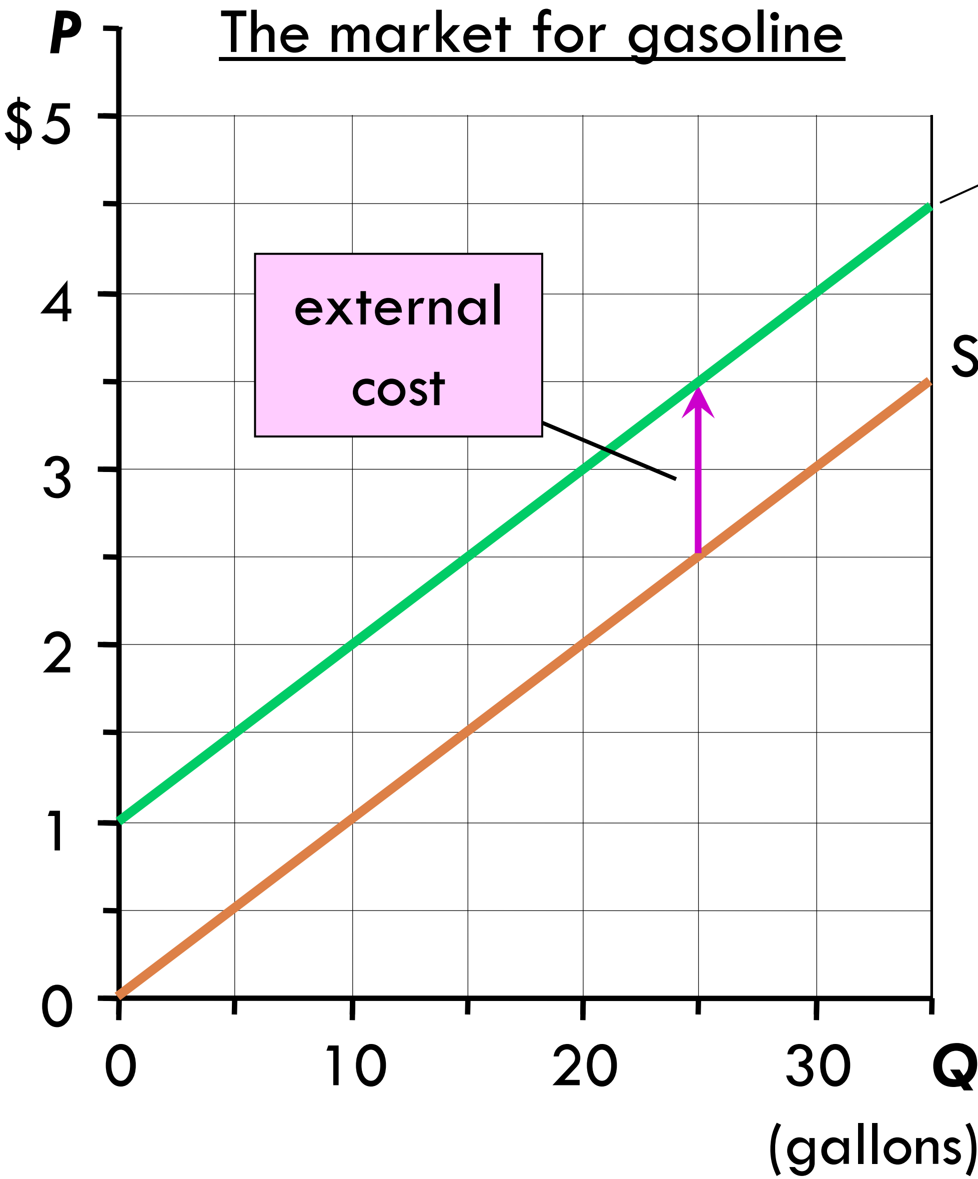


The market eq'm maximizes consumer + producer surplus.

Supply curve shows **private cost**, the costs directly incurred by sellers.

Demand curve shows **private value**, the value to buyers (the prices they are willing to pay).

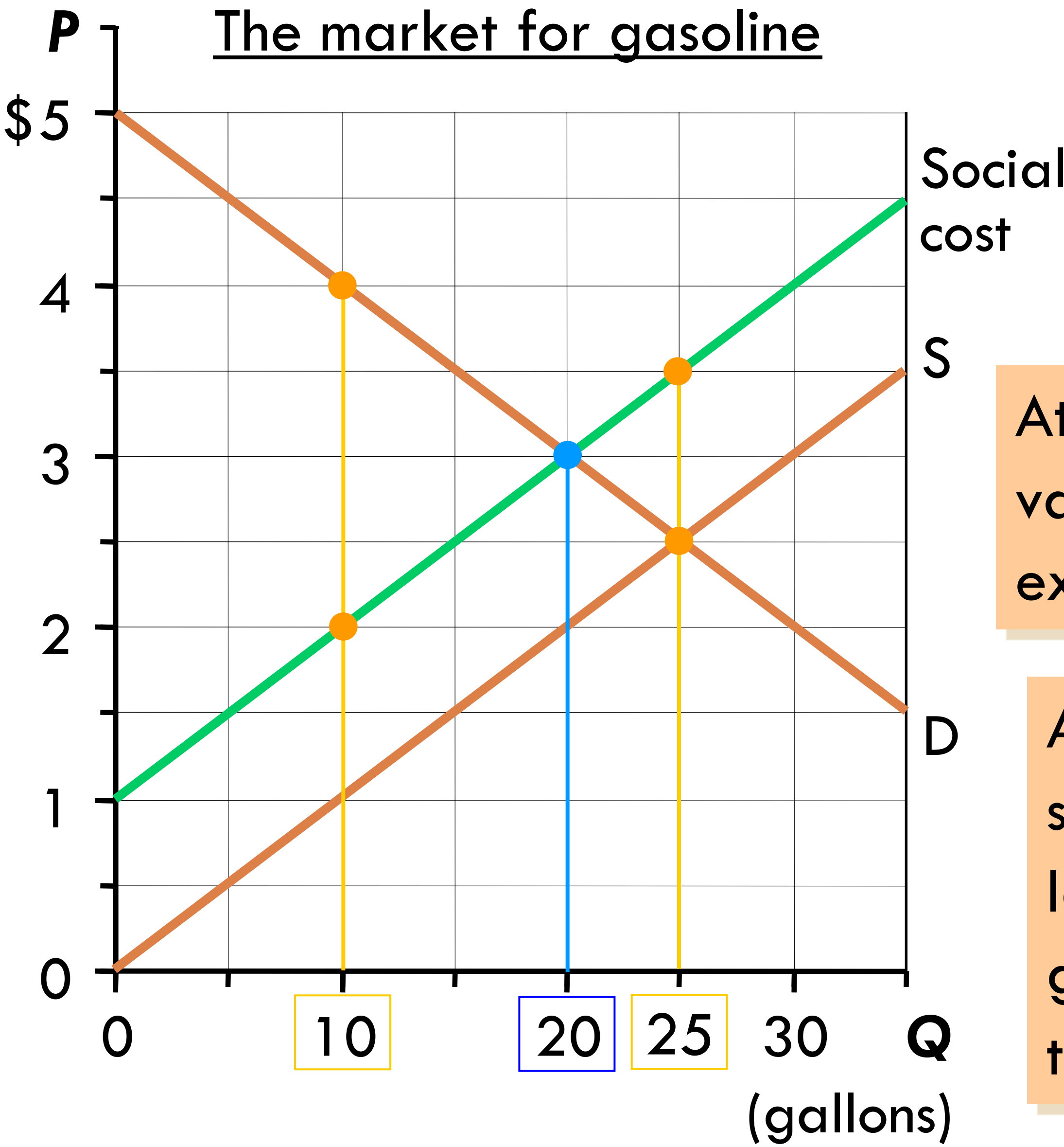
Analysis of a Negative Externality



______ = private + external cost

______ = value of the negative impact on bystanders = $1 per gallon (value of harm from smog, greenhouse gases)

Analysis of a Negative Externality

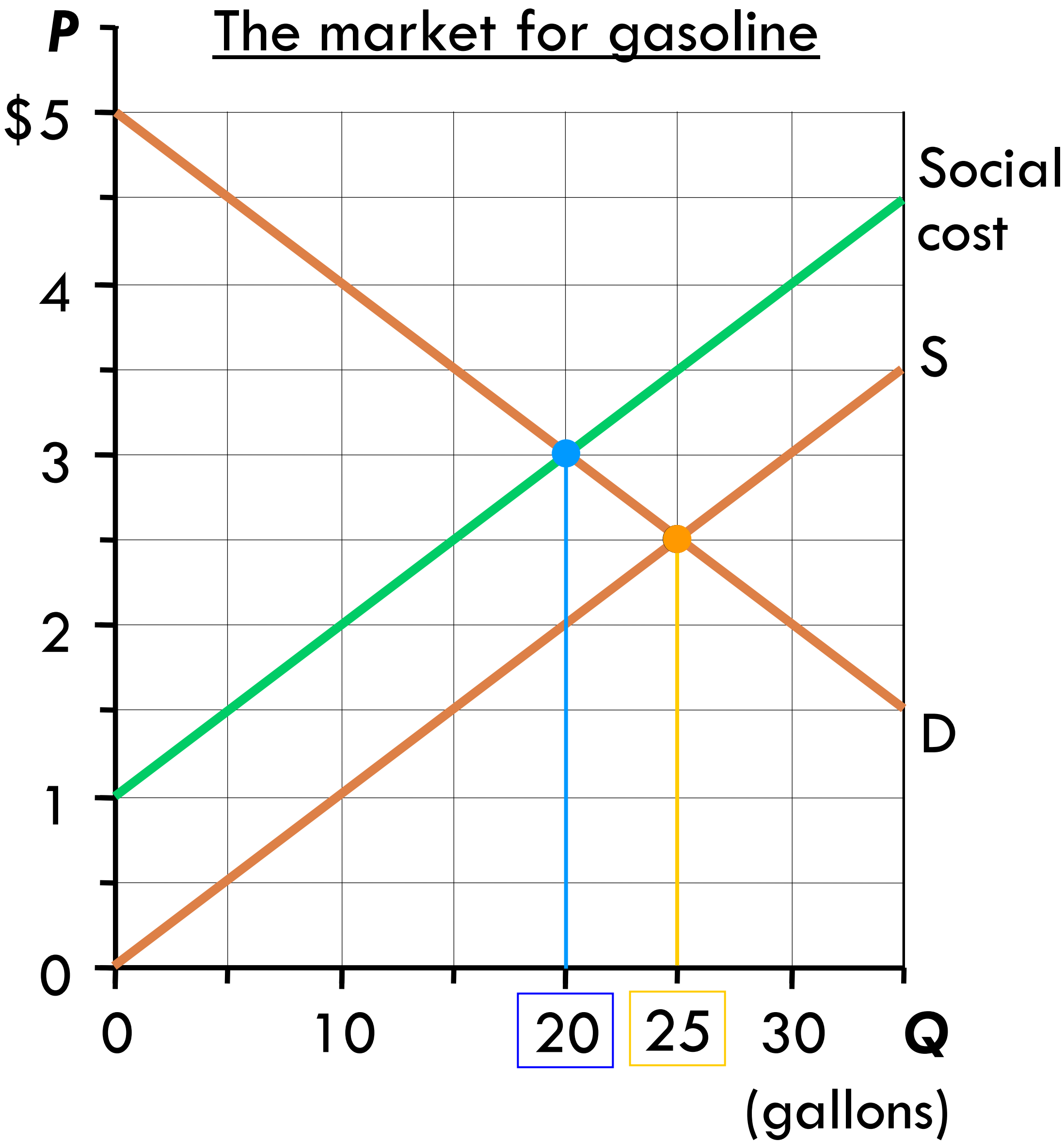


The socially optimal quantity is 20 gallons.

At any **Q** < 20, value of additional gas exceeds social cost.

At any **Q** > 20, social cost of the last gallon is greater than its value to society.

Analysis of a Negative Externality



Market eq'm (**Q** = 25) is greater than social optimum (**Q** = 20).

One solution: tax sellers $1/gallon, would shift ***S*** curve up $1.

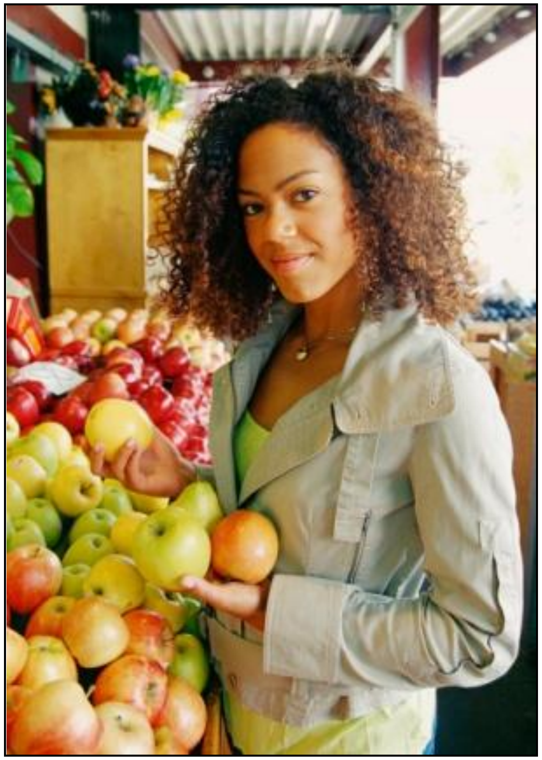
"Internalizing the Externality"

- **Internalizing the externality**: altering incentives so that people take account of the **external effects** of their actions
- In our example, the \$1/gallon tax on sellers makes sellers' costs = social costs.
- When market participants must pay social costs, ____.

  (Imposing the tax on buyers would achieve the same outcome; market **Q** would equal optimal **Q**.)

Examples of Positive Externalities

- Subsidies for renewable energy projects to reduce greenhouse gases
- Being vaccinated against contagious diseases protects not only you, but people who visit the salad bar or produce section after you.
- R&D creates knowledge others can use.
- People going to college raise the population's education level, which reduces crime and improves government.



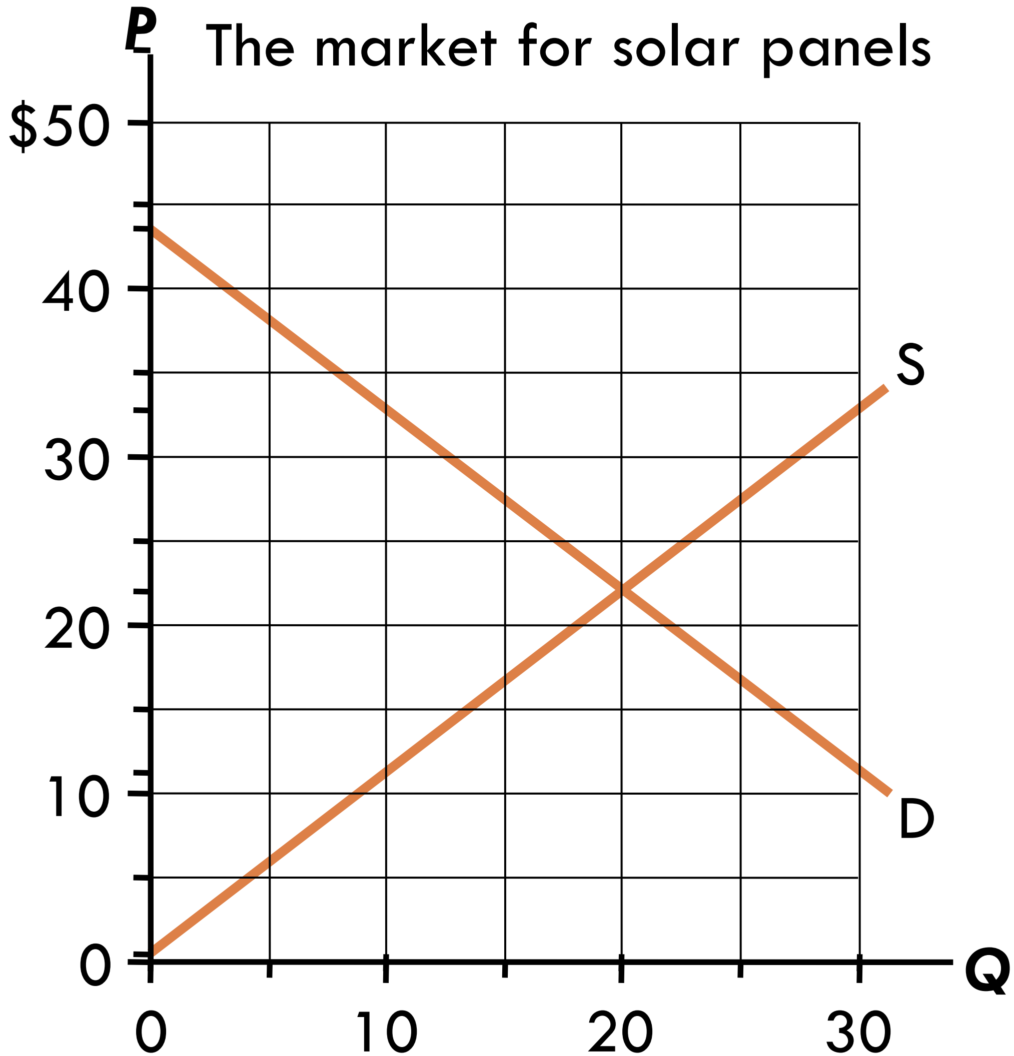
Thank you for not contaminating the fruit supply!

Positive Externalities

- In the presence of a positive externality, the **social value** of a good includes
  - ______________________ – the direct value to buyers
  - ______________________ – the value of the positive impact on bystanders
- The socially optimal **Q** maximizes welfare:
  - At any lower **Q**, the social value of additional units exceeds their cost.
  - At any higher **Q**, the cost of the last unit exceeds its social value.

ACTIVE LEARNING 1

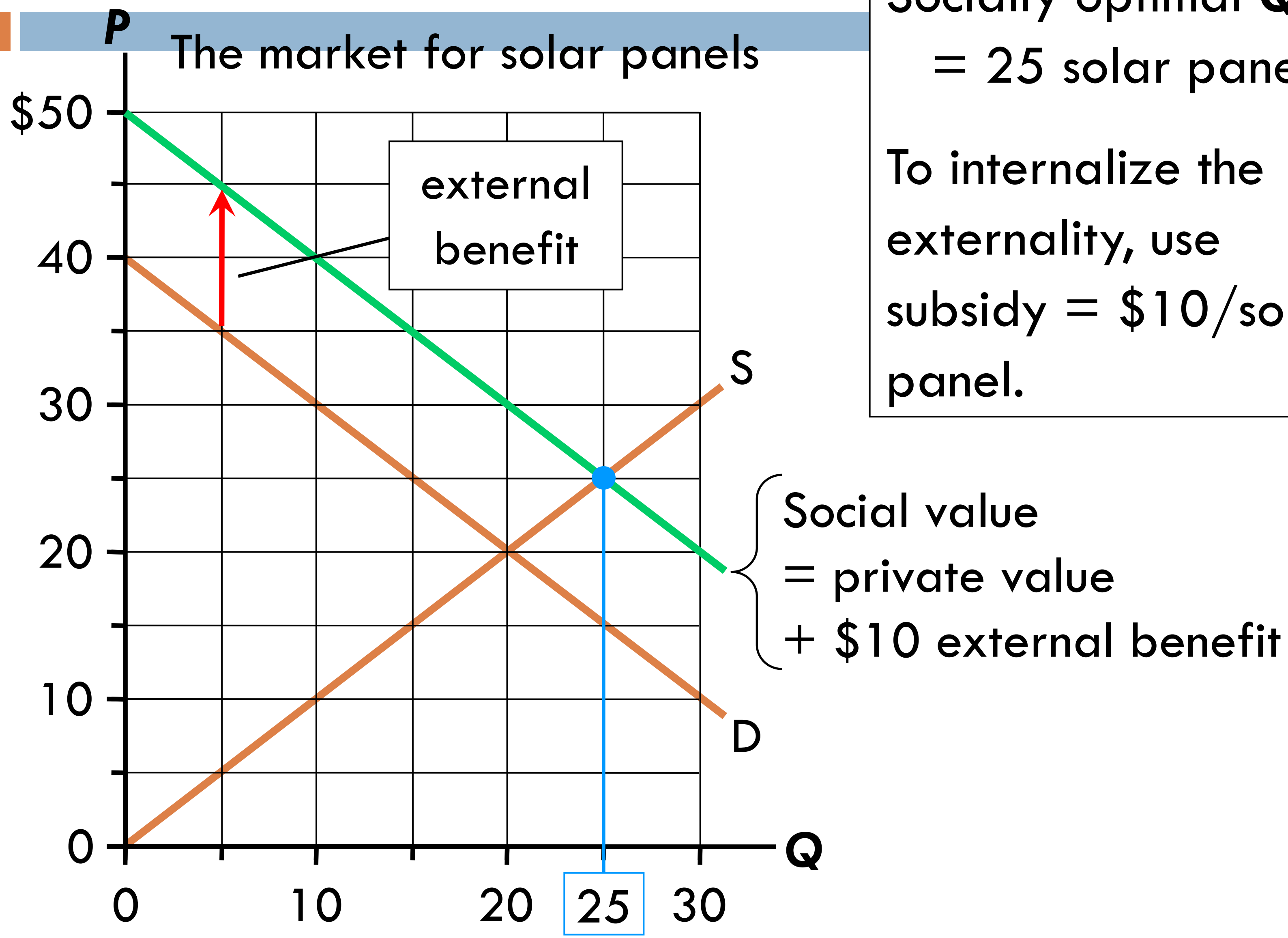
Analysis of a positive externality



External benefit = $10/solar panel

- Draw the social value curve.
- Find the socially optimal **Q**.
- What policy would internalize this externality?

ACTIVE LEARNING 1
Answers



Socially optimal **Q** = 25 solar panels.

To internalize the externality, use subsidy = $10/solar panel.

Effects of Externalities: Summary

-If negative externality

- market quantity larger than socially desirable

-If positive externality

- market quantity smaller than socially desirable

-To remedy the problem,
"internalize the externality"

- tax goods with negative externalities
- subsidize goods with positive externalities

Public Policies Toward Externalities

Two approaches (video):

- **Command-and-control policies** regulate behavior directly. Examples:
  - limits on quantity of pollution emitted
  - requirements that firms adopt a particular technology to reduce emissions
- **Market-based policies** provide incentives so that private decision-makers will choose to solve the problem on their own. Examples:
  - corrective taxes and subsidies
  - tradable pollution permits

Taxes

- The govt levies taxes on many goods & services to raise revenue to pay for national defense, public schools, etc.
- The govt can make buyers or sellers pay the tax.
- The tax can be a % of the good's price (ad valorum tax), or a specific amount for each unit sold.
  - For simplicity, we analyze **per-unit taxes** only.

Corrective Taxes & Subsidies

- **Corrective tax**: a tax designed to induce private decision-makers to take account of the social costs that arise from a ______________________________
- Also called ______________________________after Arthur Pigou (1877-1959).
- The ideal corrective tax = **external cost**
- For activities with positive externalities, ideal corrective subsidy = **external benefit**

Carbon Tax (Pigouvian Taxes/Subsidies)

Carbon is present in every hydrocarbon fuel (coal, petroleum, and natural gas) and is released as carbon dioxide (CO_2) when they are burnt.

- CO_2 is a heat-trapping "greenhouse" gas.
- Scientists have pointed to the potential effects on the climate system of releasing greenhouse gases (GHGs) into the atmosphere (see scientific opinion on global warming).
- Since GHG emissions caused by the combustion of fossil fuels are closely related to the carbon content of the respective fuels, a tax on these emissions can be levied by taxing the carbon content of fossil fuels at any point in the product cycle of the fuel.
- From Wikipedia

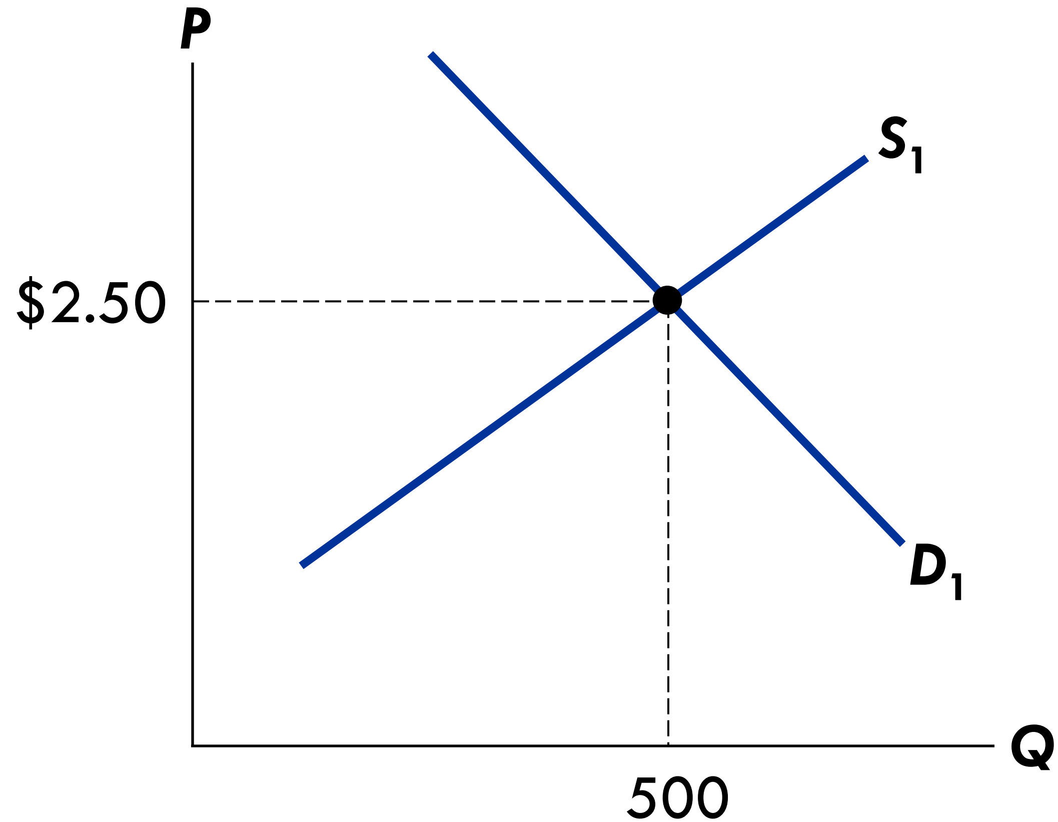
Example of a Corrective Tax: The Gas Tax

The gas tax targets three negative externalities:

- Congestion
  The more you drive, the more you contribute to congestion.
- Accidents
  Larger vehicles cause more damage in an accident.
- ____________________
  Burning fossil fuels produces greenhouse gases.

EXAMPLE: The Market for Gasoline

Eq'm
w/o tax



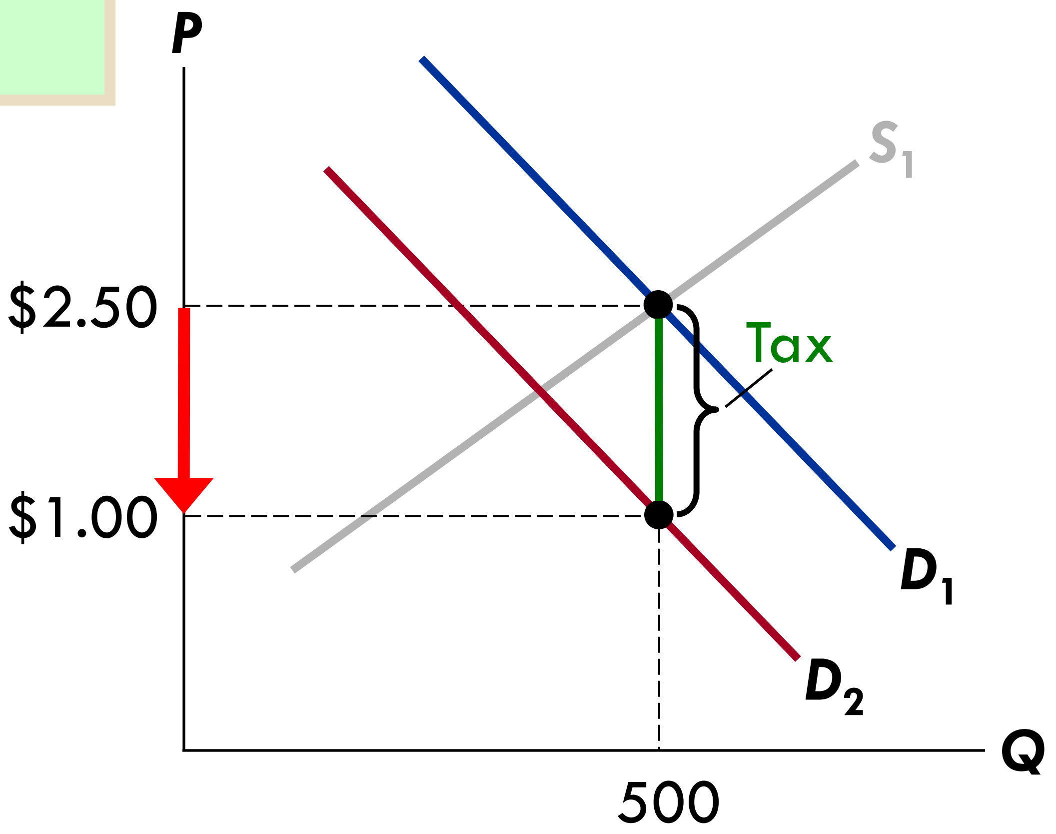
A Tax on Buyers

Hence, a tax on buyers shifts the ***D*** curve down by the amount of the tax.

P would have to fall by $1.50 to make buyers willing to buy same **Q** as before.

E.g., if ***P*** falls from $2.50 to $1.00, buyers still willing to purchase 500 gallons.

Effects of a $1.50 per unit tax on buyers



A Tax on Buyers

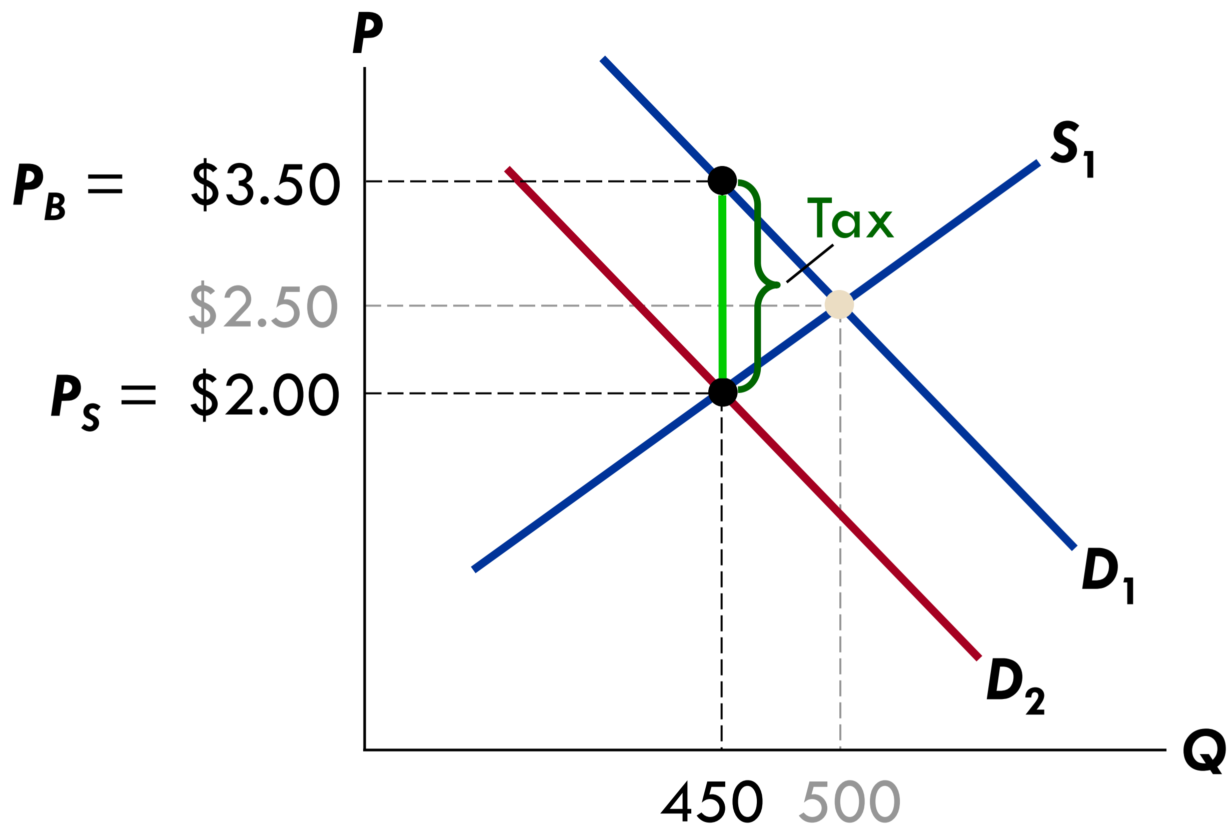
<u>New eq'm:</u>

Q = 450

Sellers receive P_S = $2.00

Buyers pay P_B = $3.50

Difference between them = $1.50 = tax



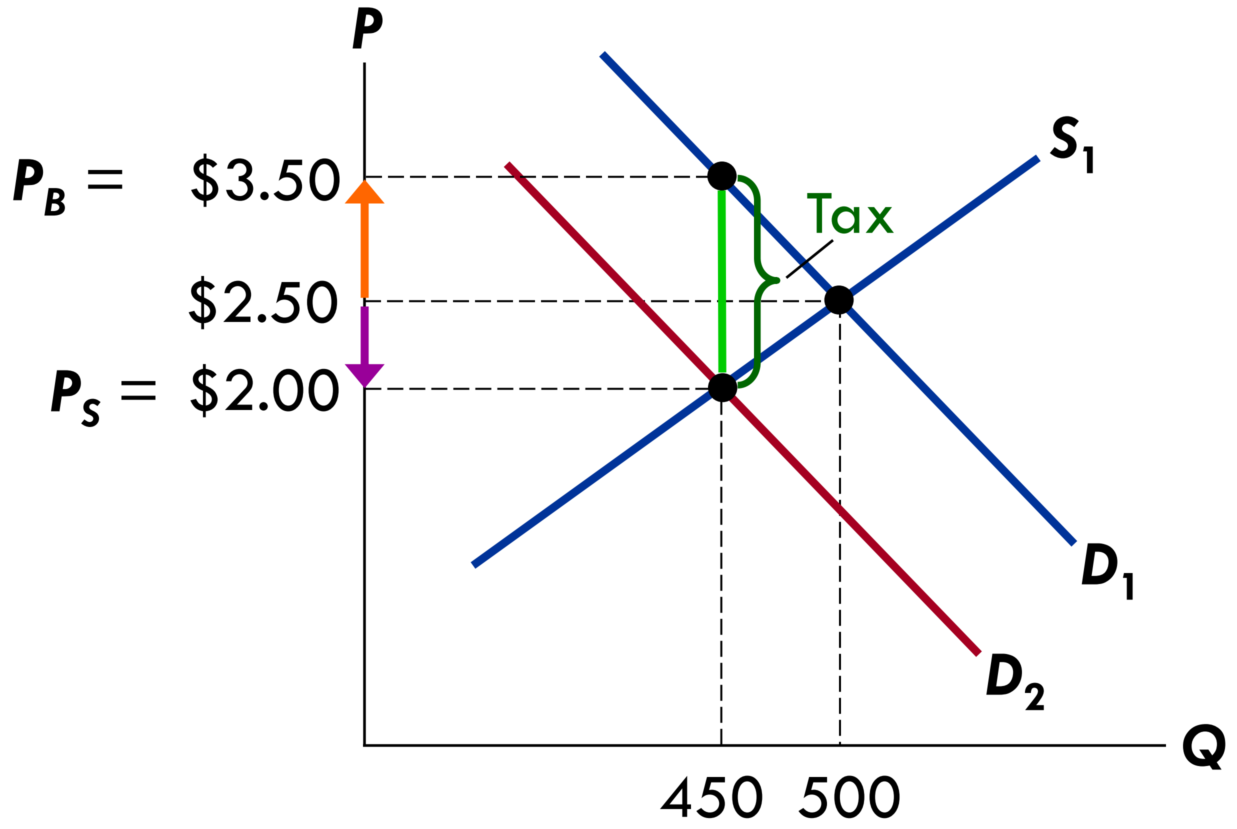
The ______________________ of a Tax:

how the burden of a tax is shared among market participants

In our example,

buyers pay $1.00 more,

sellers get $0.50 less.

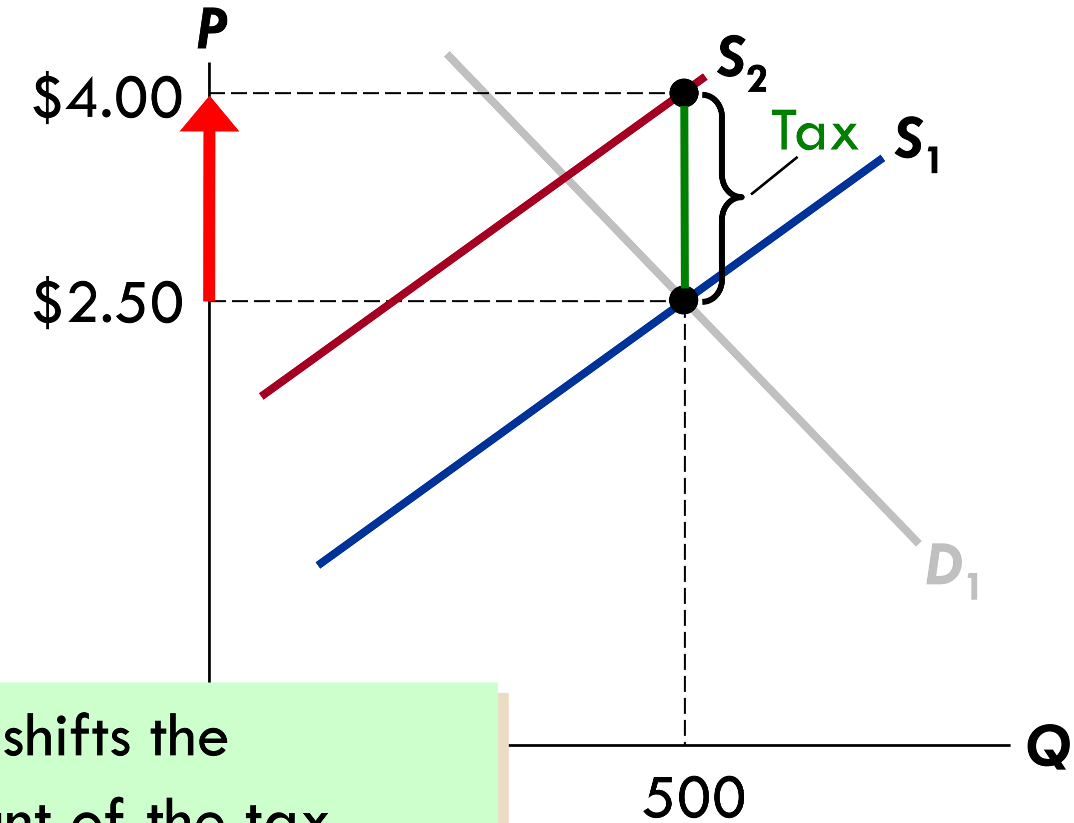


A Tax on Sellers

The tax effectively raises sellers' costs by $1.50 per gallon.

Sellers will supply 500 gallons only if ***P*** rises to $4.00, to compensate for this cost increase.

Effects of a $1.50 per unit tax on sellers



Hence, a tax on sellers shifts the ***S*** curve up by the amount of the tax.

A Tax on Sellers

<u>New eq'm:</u>

Q = 450

Buyers pay

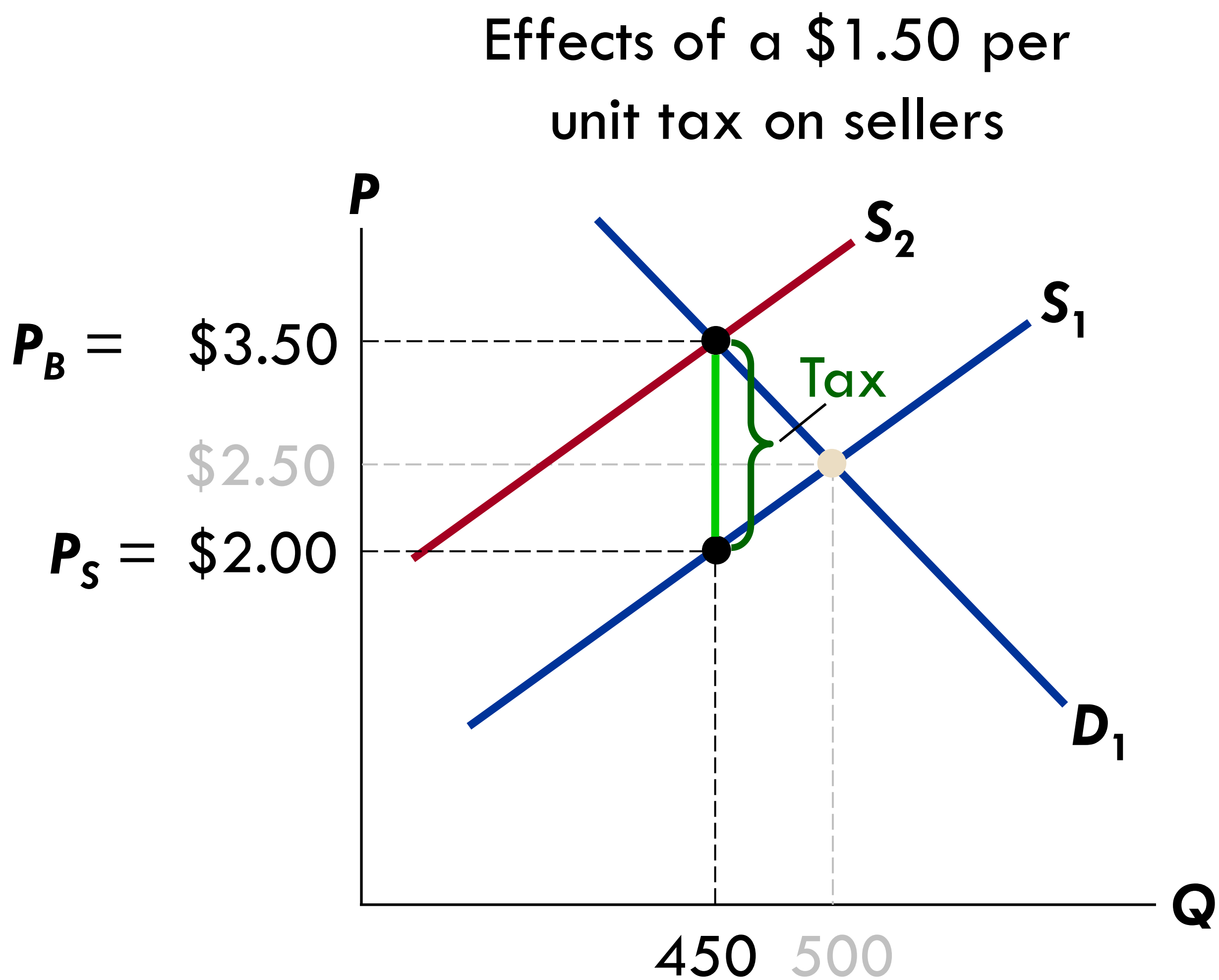
P_B = $3.50

Sellers receive

P_S = $2.00

Difference between them

= $1.50 = tax

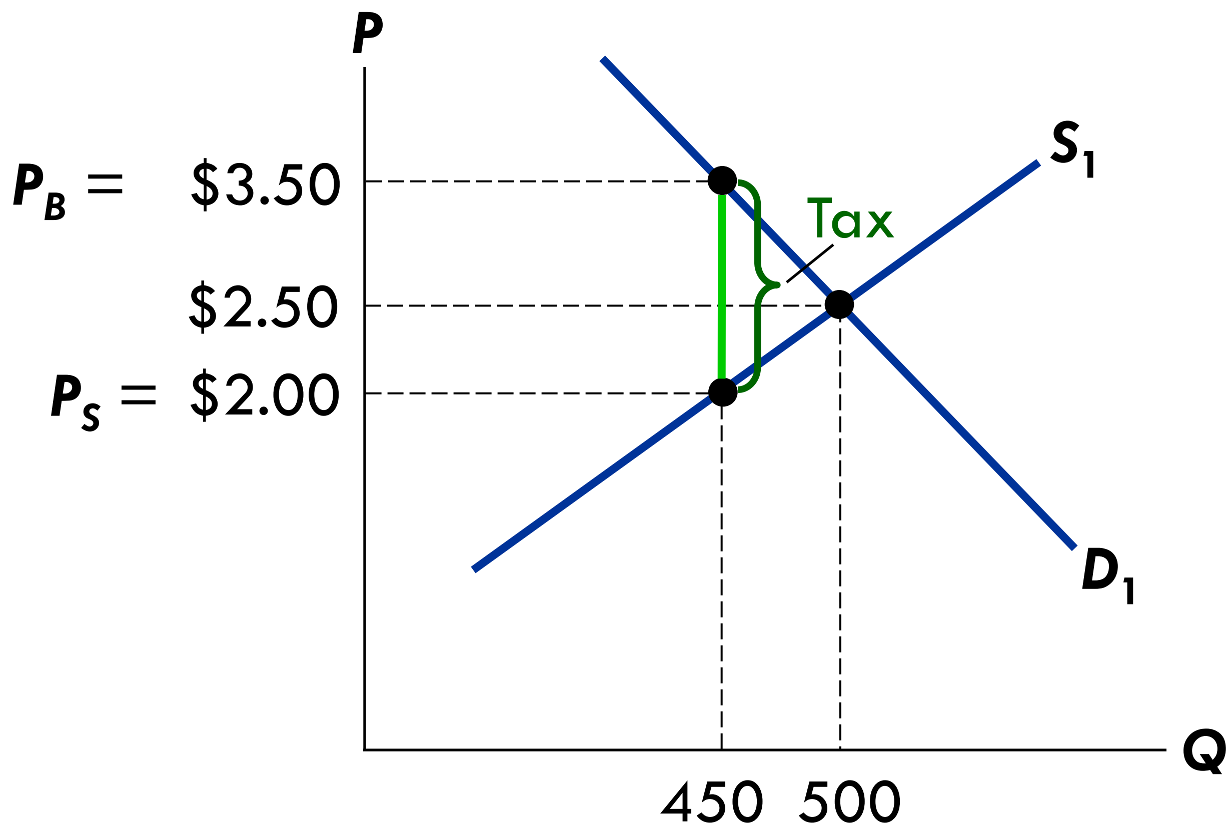


The Outcome Is the Same in Both Cases!

The effects on ***P*** and ***Q***, and the tax incidence are the same whether the tax is imposed on buyers or sellers!

What matters is this:

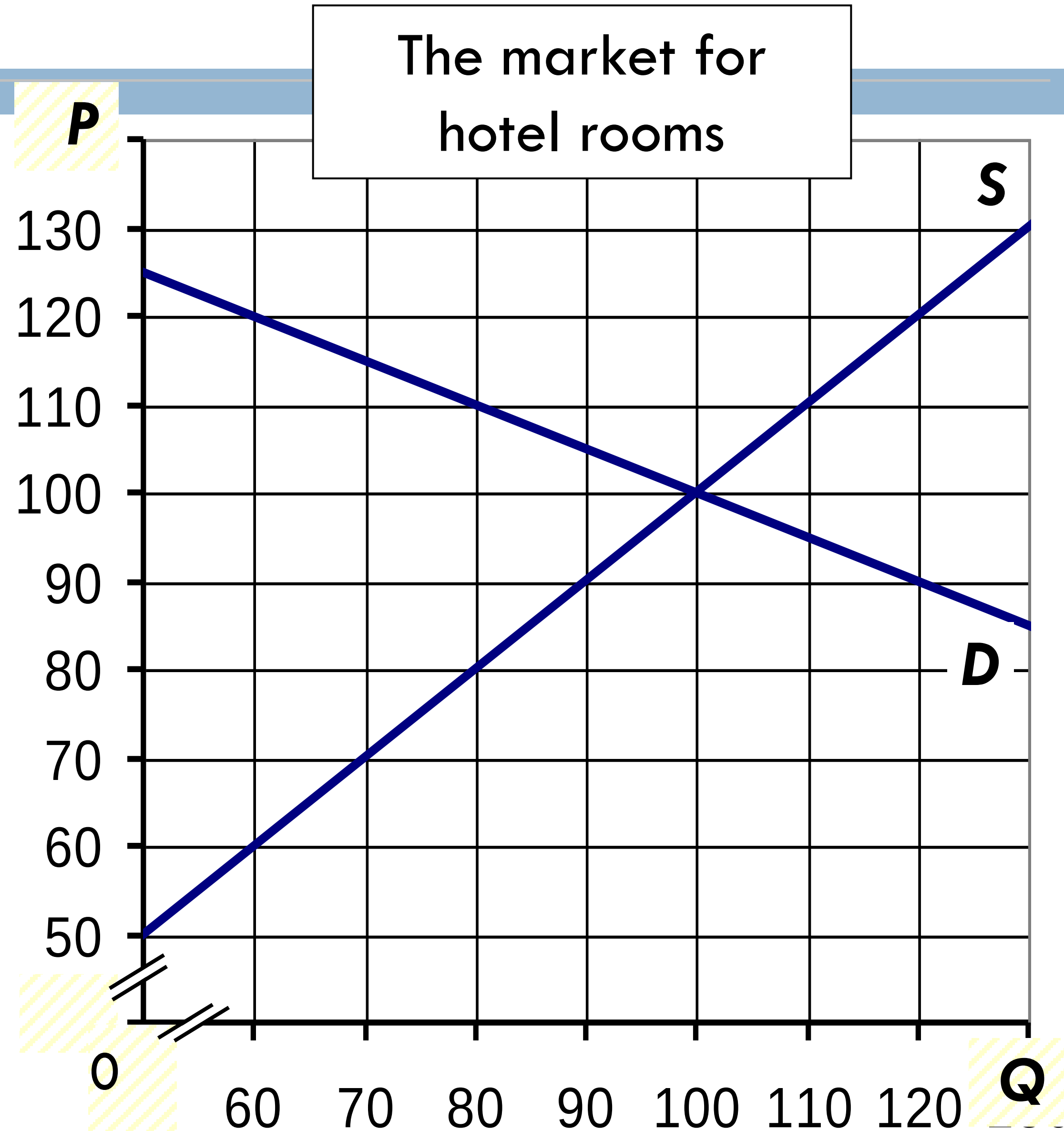
A tax drives a wedge between the price buyers pay and the price sellers receive.



ACTIVE LEARNING 2
Effects of a tax

Suppose govt imposes a tax on buyers of $30 per barrel of oil.

Find new **Q**, P_B, P_S, and incidence of tax.



ACTIVE LEARNING 2
Answers

Q = 80

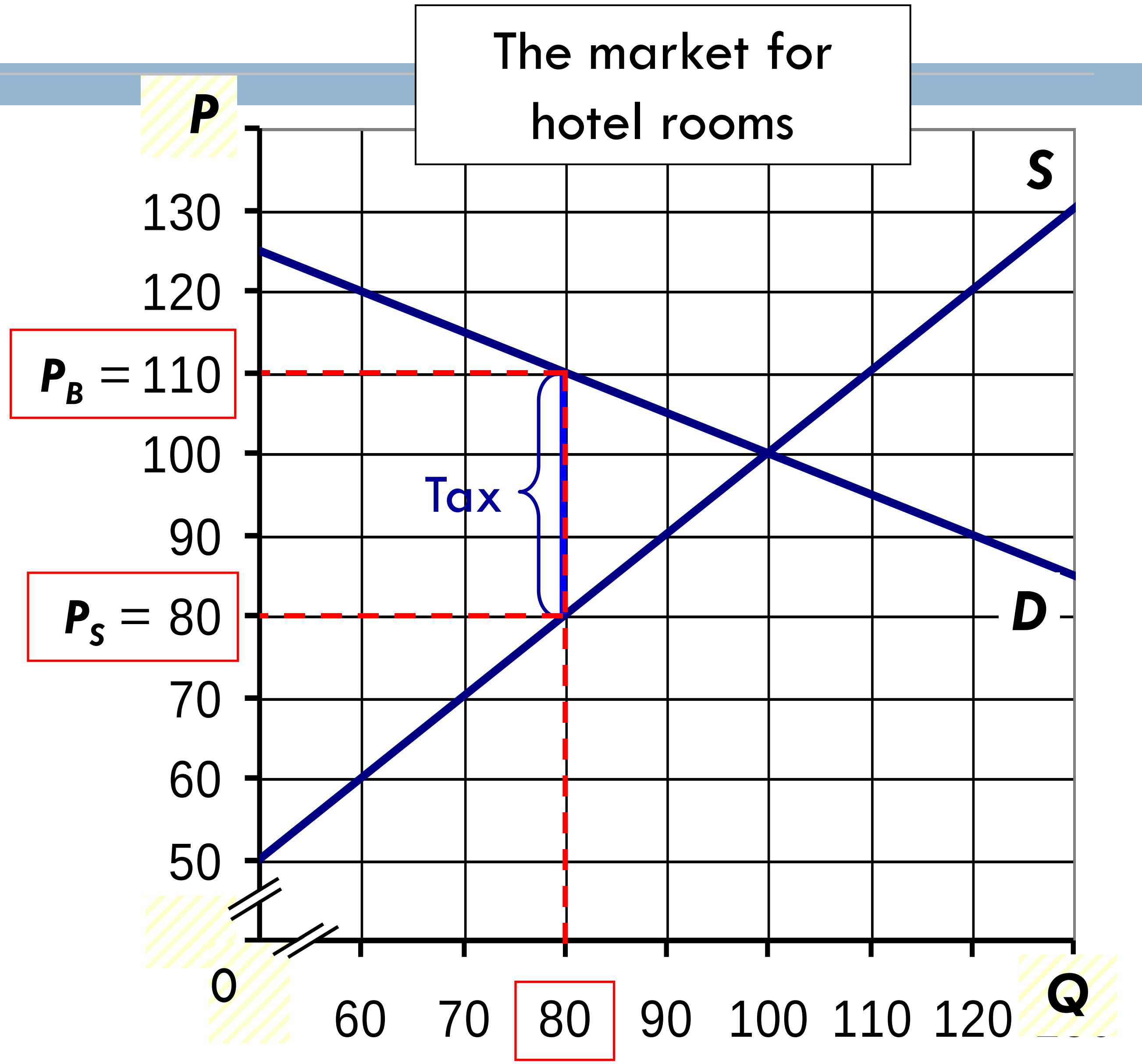
P_B = $110

P_S = $80

<u>Incidence</u>

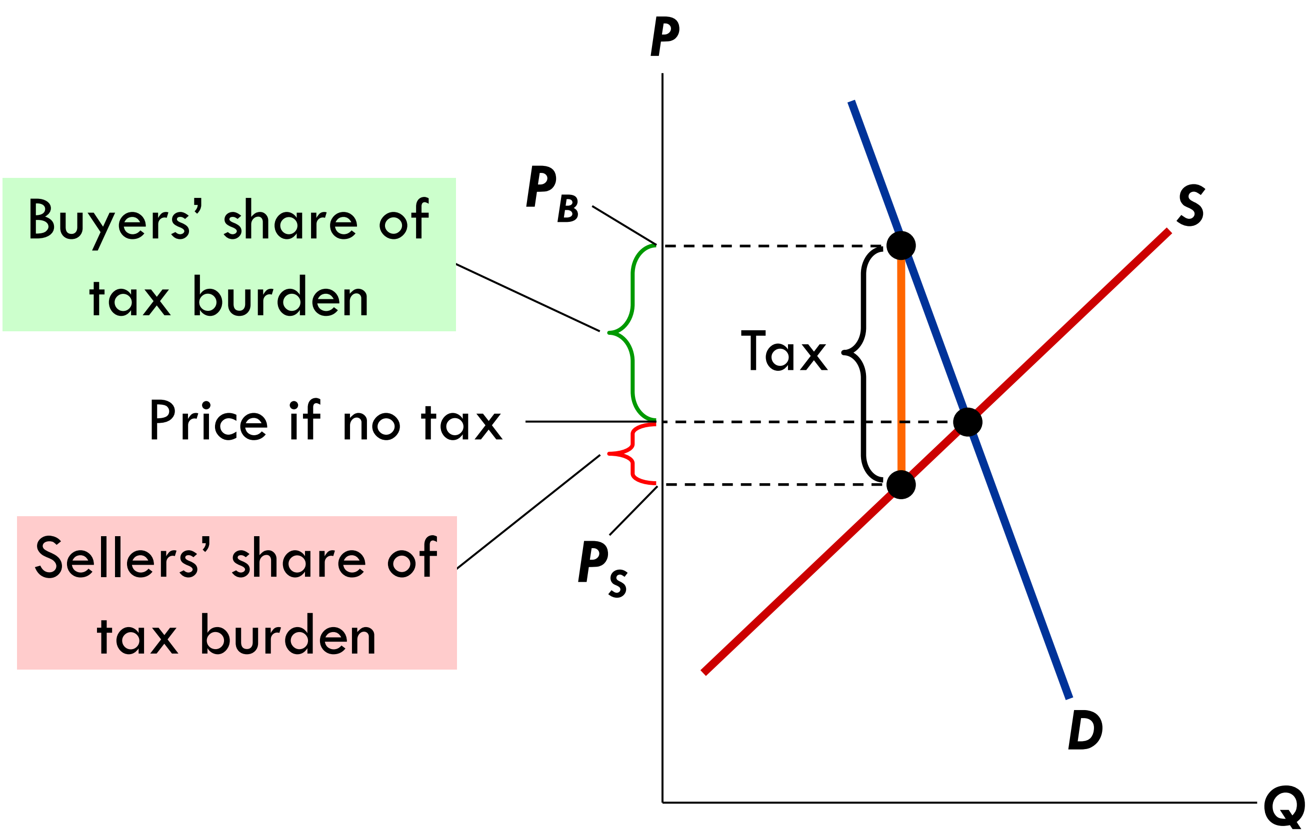
buyers: $10

sellers: $20



Elasticity and Tax Incidence

<u>CASE 1: Supply is more elastic than demand</u>

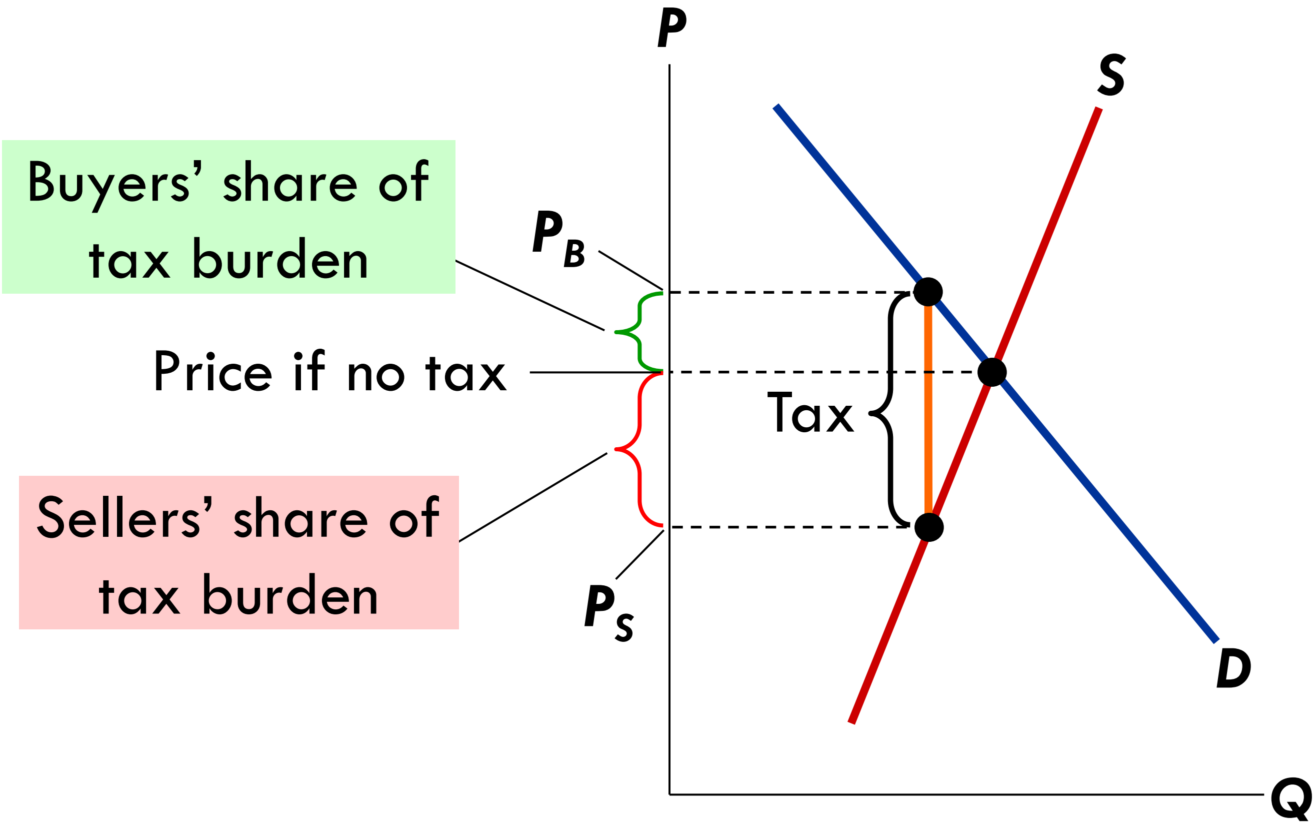


It's easier for sellers than buyers to leave the market.

So buyers bear most of the burden of the tax.

Elasticity and Tax Incidence

CASE 2: Demand is more elastic than supply



It's easier for buyers than sellers to leave the market.

Sellers bear most of the burden of the tax.

Corrective Taxes & Subsidies

- Other taxes and subsidies distort incentives and move economy away from the social optimum.
- Corrective taxes & subsidies
  - align private incentives with society's interests
  - make private decision-makers take into account the external costs and benefits of their actions
  - move economy toward a more efficient allocation of resources.

Corrective Taxes vs. Regulations

- Different firms have different costs of pollution abatement (taking measures to cut pollution).
- Efficient outcome: Firms with the lowest abatement costs reduce pollution the most.
- A pollution tax is efficient:
  - Firms with low abatement costs will reduce pollution to reduce their tax burden.
  - Firms with high abatement costs have greater willingness to pay tax.
- In contrast, a regulation requiring all firms to reduce pollution by a specific amount not efficient.

Corrective Taxes vs. Regulations

Corrective taxes may be better for the environment:

- The corrective tax gives firms incentive to continue reducing pollution as long as the cost of doing so is less than the tax.
- If a cleaner technology becomes available, the tax gives firms an incentive to adopt it.
- In contrast, firms have no incentive for further reduction beyond the level specified in a regulation.

Tradable Pollution Permits (Cap and Trade)

- A tradable pollution permits system reduces pollution at lower cost than regulation.
  - Firms with low cost of reducing pollution sell whatever permits they can.
  - Firms with high cost of reducing pollution buy permits.
- Result: Pollution reduction is concentrated among those firms with lowest costs.

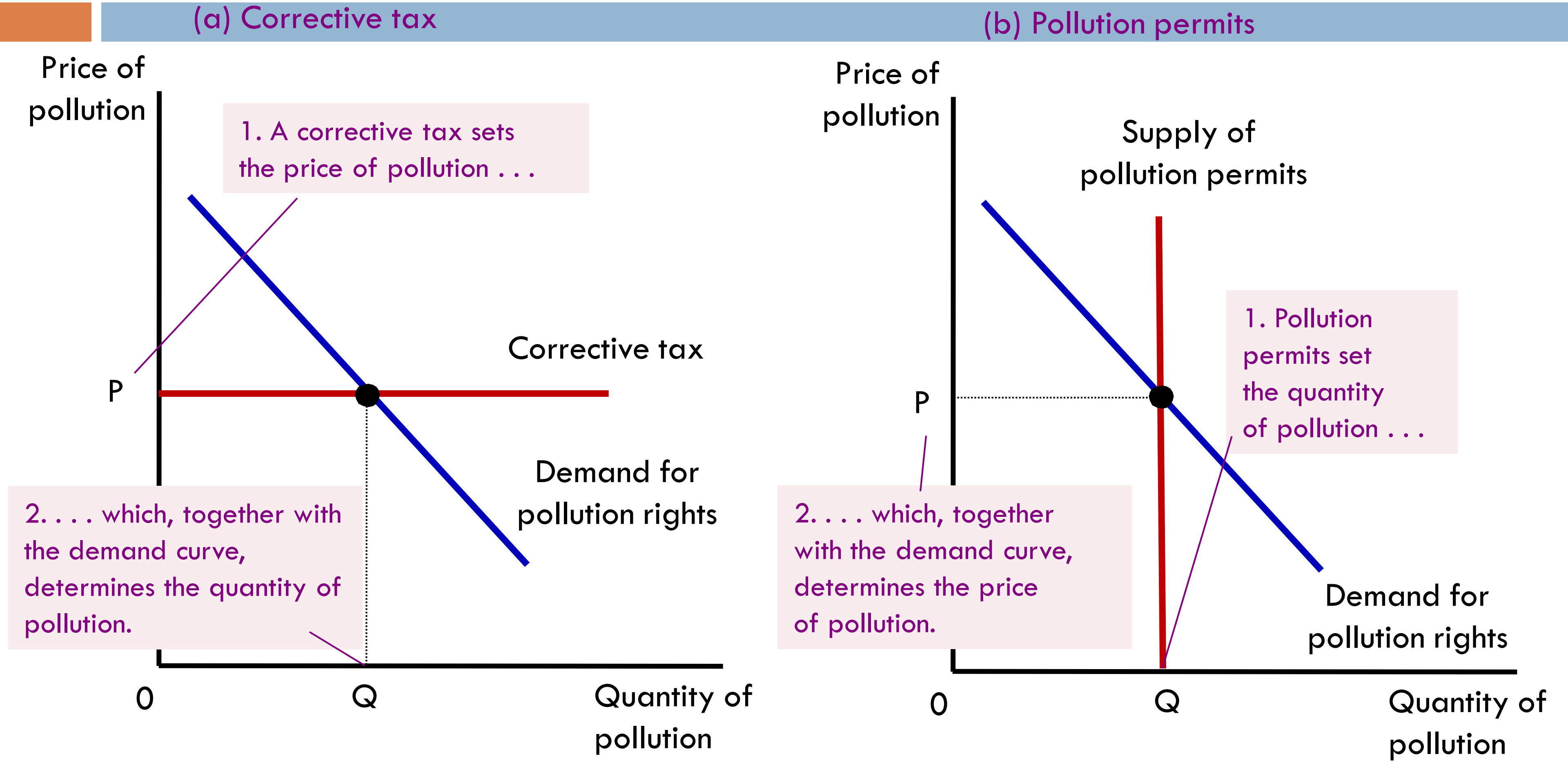
Tradable Pollution Permits in the Real World

- SO_2 permits traded in the U.S. since 1995.
- Nitrogen oxide permits traded in the northeastern U.S. since 1999.
- Carbon emissions permits traded in Europe since January 1, 2005.
- As of June 2008, Barack Obama and John McCain each propose "cap and trade" systems to reduce greenhouse gas emissions.
- Waxman-Markey bill was passed in 2009 (see link for details): proposed a cap and trade system

Corrective Taxes vs. Tradable Pollution Permits (i.e. Cap and Trade)

- Like most demand curves, firms' demand for the ability to pollute is a downward-sloping function of the "price" of polluting.
  - A corrective tax raises this price and thus reduces the quantity of pollution firms demand.
  - A ______________________________system restricts the supply of pollution rights, has the same effect as the tax.
- When policymakers do not know the position of this demand curve, the permits system achieves pollution reduction targets more precisely.

The equivalence of corrective taxes & pollution permits



In panel (a), the EPA sets a price on pollution by levying a corrective tax, and the demand curve determines the quantity of pollution. In panel (b), the EPA limits the quantity of pollution by limiting the number of pollution permits, and the demand curve determines the price of pollution. The price and quantity of pollution are the same in the two cases.

Objections to the Economic Analysis of Pollution

- Some politicians, many environmentalists argue that no one should be able to "buy" the right to pollute, cannot put a price on the environment.
- However, people face tradeoffs. The value of clean air & water must be compared to their cost.
- The market-based approach reduces the cost of environmental protection, so it should increase the public's demand for a clean environment.

Private Solutions to Externalities

Types of private solutions:

- Moral codes and social sanctions, e.g., the "Golden Rule"
- Charities, e.g., the Sierra Club
- Contracts between market participants and the affected bystanders
- "Tragedy of the Commons"-(video): In economics, the **tragedy of the commons** is the depletion of a shared resource by individuals, acting independently and rationally according to each one's self-interest, despite their understanding that depleting the common resource is contrary to their long-term best interests.- Wikipedia

Examples of “Environmental Tragedies”

- Uncontrolled human population growth leading to overpopulation.
- Air, whether ambient air polluted by industrial emissions and cars among other sources of air pollution, or indoor air.
- Forests – Frontier logging of old growth forest and slash and burn
- Energy resources and climate – Burning of fossil fuels and consequential global warming

Private Solutions to Externalities

- ______________________________:
  If private parties can costlessly bargain over the allocation of resources, they can solve the externalities problem on their own.
- Key point: Government is not needed to remedy external costs or benefits where:
  - 1. property ownership is clearly defined
  - 2. the number of people involved is small
  - 3. bargaining costs are negligible
  - Government should confine its role to encouraging bargaining between affected individuals or groups
    - Conceived by Ronald Coase at the University of Chicago:

The Coase Theorem: An Example

Dick owns a dog named Spot.

Negative externality:
Spot's barking disturbs Jane,
Dick's neighbor.

The socially efficient outcome maximizes Dick's + Jane's well-being.

- If Dick values having Spot more than Jane values peace & quiet, the dog should stay.

See Spot bark.

Coase theorem: The private market will reach the efficient outcome on its own…

The Coase Theorem: An Example

- CASE 1:
  Dick has the right to keep Spot.
  Benefit to Dick of having Spot = $500
  Cost to Jane of Spot's barking = $800
- Socially efficient outcome:
  Spot goes bye-bye.
- Private outcome:
  Jane pays Dick $600 to get rid of Spot,
  both Jane and Dick are better off.
- Private outcome = efficient outcome.

The Coase Theorem: An Example

- CASE 2:
  Dick has the right to keep Spot.
  Benefit to Dick of having Spot = $1000
  Cost to Jane of Spot's barking = $800
- Socially efficient outcome:
  See Spot stay.
- Private outcome:
  Jane not willing to pay more than $800,
  Dick not willing to accept less than $1000,
  so Spot stays.
- Private outcome = efficient outcome.

The Coase Theorem: An Example

- CASE 3:
  Jane has the legal right to peace & quiet.
  Benefit to Dick of having Spot = \$800
  Cost to Jane of Spot's barking = \$500
- Socially efficient outcome: Dick keeps Spot.
- Private outcome: Dick pays Jane \$600 to put up with Spot's barking.
- Private outcome = efficient outcome.

The private market achieves the efficient outcome regardless of the initial distribution of rights.

Why Private Solutions Do Not Always Work

1. ________________________________:
   The costs parties incur in the process of agreeing to and following through on a bargain.
   These costs may make it impossible to reach a mutually beneficial agreement.
2. Stubbornness:
   Even if a beneficial agreement is possible,
   each party may hold out for a better deal.
3. Coordination problems:
   If # of parties is very large, coordinating them may be costly, difficult, or impossible.

Example: Global warming: affects millions or people in many nations. The vast number of affected parties could not individually negotiate an agreement to remedy this problem. Instead, governments negotiations may be necessary.

Normative Criteria for Decision Making

- Evaluating Predefined Options: Benefit–Cost Analysis
  - Let B be the benefits from a proposed action and C be the costs. Our decision rule would then be:
    - If B > C, support the action
    - Otherwise, oppose the action

Normative Criteria for Decision Making

- Total benefits are the value of total willingness to pay, which is the area under the market demand curve from the origin to the allocation of interest.

- Opportunity cost is the net benefit lost when specific environmental services are forgone in the conversion to the new use.

- Total costs is the sum of marginal opportunity costs, which is the area under the marginal cost curve.

Normative Criteria for Decision Making

- Comparing Benefits and Costs Across Time
  - Present Value of a *one-time* net benefit (B_n) received *n* years from now is

$$PV[B_n] = \frac{B_n}{(1+r)^n}$$

Where *r* is the interest rate

TABLE 3.1 Demonstrating Present Value Calculations

Year	1	2	3	4	5	Sum
Annual Amounts	$3,000	$5,000	$6,000	$10,000	$12,000	$36,000
Present Value (r = 0.06)	$2,830.19	$4,449.98	$5,037.72	$7,920.94	$8,967.10	$29,205.92

Normative Criteria for Decision Making

- First Equimarginal Principle (the “Efficiency Equimarginal Principle”):
  - Net benefits are maximized when the marginal benefits from an allocation equal the marginal costs.
- Pareto optimality:
  - Allocations are said to be Pareto optimal if no other feasible allocation could benefit at least one person without any deleterious effects on some other person.

Applying the Concepts

- Pollution Control
  - Benefits include, not limited to, reduced death rate, lower incidences of chronic bronchitis and other diseases, better visibility, improved agricultural productivity and etc.
  - Costs include
    - 1) higher costs passed to consumers such as installing, operating and maintaining pollution control equipment
    - 2) administrative costs such as designing, implementing, monitoring relevant policies

TABLE 3.3 Summary Comparison of Benefits and Costs from the Clean Air Act-1990–2020 (Estimates in Million 2006$)

	Annual Estimates			Present Value Estimate
	2000	2010	2020	1990–2020
Monetized Direct Costs:				
Low[1]				
Central	$20,000	$53,000	$65,000	$380,000
High[1]				
Monetized Direct Benefits:				
Low[2]	$90,000	$160,000	$250,000	$1,400,000
Central	$770,000	$1,300,000	$2,000,000	$12,000,000
High[2]	$2,300,000	$3,800,000	$5,700,000	$35,000,000
Net Benefits:				
Low	$70,000	$110,000	$190,000	$1,000,000
Central	$750,000	$1,200,000	$1,900,000	$12,000,000
High	$2,300,000	$3,700,000	$5,600,000	$35,000,000
Benefit/Cost Ratio:				
Low[3]	5/1	3/1	4/1	4/1
Central	39/1	25/1	31/1	32/1
High[3]	115/1	72/1	88/1	92/1

[1]The cost estimates for this analysis are based on assumptions about future changes in factors such as consumption patterns, input costs, and technological innovation. We recognize that these assumptions introduce significant uncertainty into the cost results; however, the degree of uncertainty or bias associated with many of the key factors cannot be reliably quantified. Thus, we are unable to present specific low and high cost estimates.

[2]Low and high benefit estimates are based on primary results and correspond to 5th and 95th percentile results from statistical uncertainty analysis, incorporating uncertainties in physical effects and valuation steps of benefits analysis. Other significant sources of uncertainty not reflected include the value of unquantified or unmonetized benefits that are not captured in the primary estimates and uncertainties in emissions and air quality modeling.

[3]The low benefit/cost ratio reflects the ratio of the low benefits estimate to the central costs estimate, while the high ratio reflects the ratio of the high benefits estimate to the central costs estimate. Because we were unable to reliably quantify the uncertainty in cost estimates, we present the low estimate as "less than X," and the high estimate as "more than Y," where X and Y are the low and high benefit/cost ratios, respectively.

Sources: U.S. Environmental Protection Agency, THE BENEFITS AND COSTS OF THE CLEAN AIR ACT, 1970 to 1990 (Washington, DC: Environmental Protection Agency, 1997), Table 18, p. 56;. and the U.S. Environmental Protection Agency Office of Air and Radiation, THE BENEFITS AND COSTS OF THE CLEAN AIR ACT, 1990 to 2020 – Summary Report, 8/16/2010 and Full Report available at http://www.epa.gov/oar/sect812/prospective2.html (accessed on 12/31/2010).

Applying the Concepts

- Issues in Benefit Estimation
  - Primary Versus Secondary Effects
    - Considering both primary and secondary consequences while implementing environmental projects
  - Accounting Stance
    - Who benefits? The accounting stance refers to the geographic scale at which the benefits are measured.

Applying the Concepts

- Approaches to Cost Estimation
  - The Survey Approach
    - Involves asking polluters about their control costs
  - The Engineering Approach
    - Using engineering information to estimate the technologies available and the costs of purchasing and using those technologies.
  - The Combined Approach
    - Combining both survey and engineering approaches

Impact Analysis

- An impact analysis attempts to quantify the consequences of various actions.
- Impact analysis places a large amount of relatively undigested information at the disposal of the policy-maker.
- Presentation: The Dunes Sagebrush Lizard-See Supplemental Items on Blackboard

The Science of Climate Change

- Greenhouse gases absorb infrared radiation, trapping heat that would otherwise radiate into space.
  - Carbon dioxide most abundant
  - Emissions of these gases increasing over time
- Intergovernmental Panel on Climate change (IPCC) reported in 2007 that most warming over last 250 years can be attributable to human activity.

The Science of Climate Change

- IPCC's findings:
  - CO_2 increases due to use of fossil fuels and land-use change, methane/NO_2 due to agriculture
  - Warming is unequivocal
  - Human-induced warming and sea-level rise will continue for centuries, even if stabilized
  - Projected impacts are contracting snow cover, shrinking sea ice, increasing weather events
- Impacts of rising temps, rising seas, and more severe weather?:
  - Effects on physical and biological systems
  - Natural systems (rain forests, coral reefs) vulnerable
  - Developing countries to feel most severe effects
  - Adaptation is necessary **now**

Negotiations over Climate Change Policy

Characterizing the Broad Strategies

What can be done? Three strategies—

- Climate engineering (geoengineering): two categories
  - Carbon dioxide removal—air capture, ocean fertilization
  - Solar-radiation management—injecting stratospheric aerosols
- Adaptation: modify natural or human systems to minimize harm
- Mitigation: attempts to moderate the temperature rise by reducing emissions, increase planet's capacity to absorb greenhouse gases

The Precedent: Reducing Ozone-Depleting Gases

The Evolution of International Agreements on Climate Change

- The Kyoto Protocol (effective February 2005)allows for implementation mechanisms that involve tradable permits.
  - (a) Emissions Trading allows trading of the national quotas among countries listed in Annex B.
  - (b) Joint Implementation allows Annex B countries to receive emission reduction credits when they help finance projects in another Annex B country.
  - (c) The Clean Development Mechanism allows Annex B parties to finance emission reduction projects in non-Annex B countries (e.g. developing countries) and receive certified emission reductions for doing so.

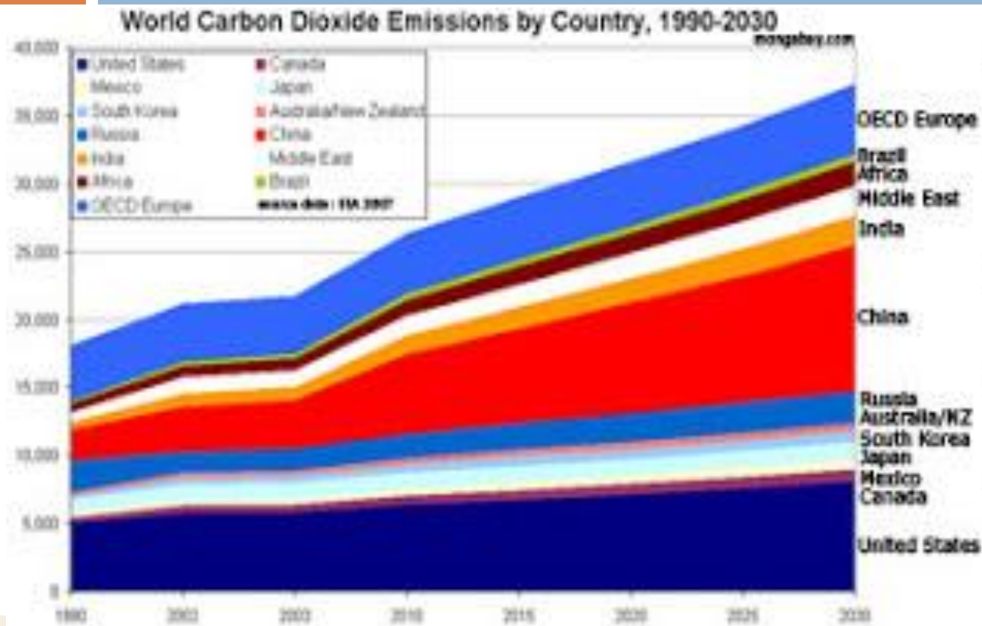
Complementary Strategies

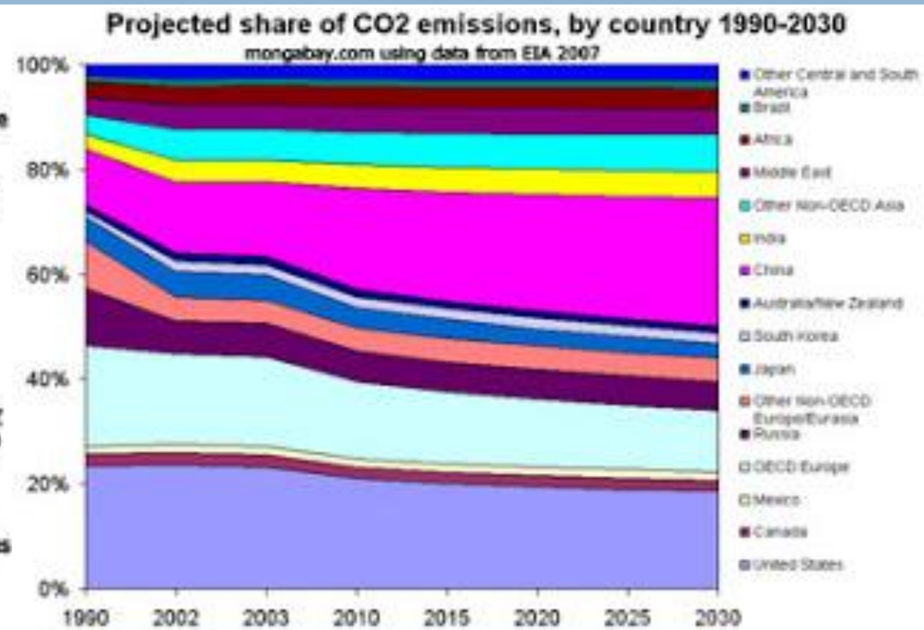
- The Prototype Carbon Fund (PCF) was established by the World Bank. The PCF acts as a "greenhouse gas mutual fund." Investors receive a pro rata share of the emission reductions.
- The Global Environmental Facility (GEF) funds projects designed to reduce the impacts of climate change through loans or grants. The GEF uses a marginal-external-cost rule when evaluating a project.
- Horizon 2020 (EU): "Resource efficiency will help stimulate technological innovation, boost employment in the fast developing 'green technology' sector, open up new export markets and benefit consumers through more sustainable products."

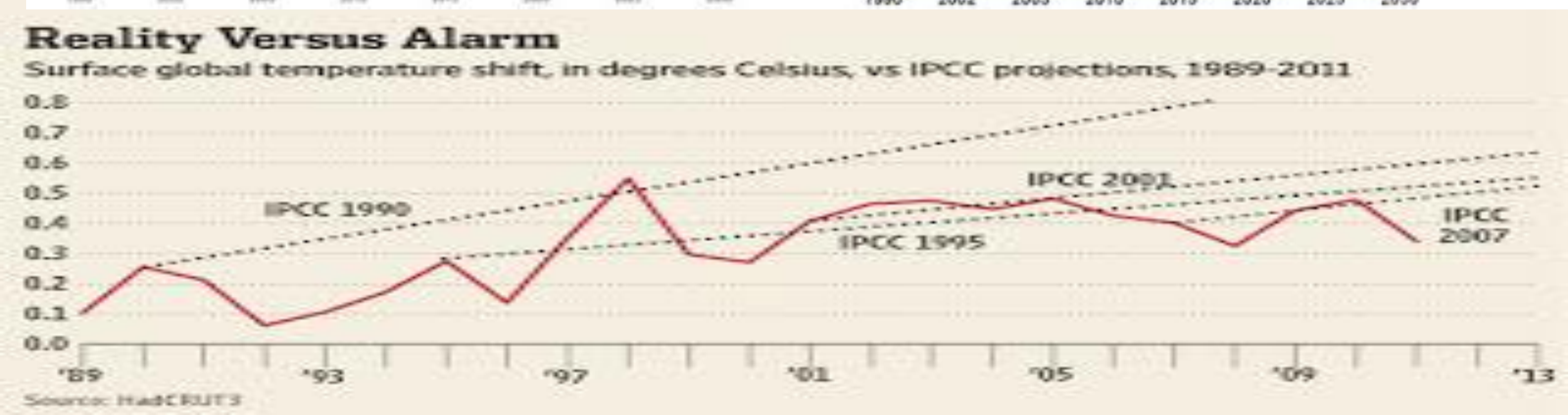
Creating Incentives for Participation in Climate Change Agreements

- Game theory has been used to study participation in agreements with public good problems.
- Policies can make participation more likely by increasing the net benefits from participation.
- "Issue linkage" is a strategy where countries simultaneously negotiate a climate change agreement and another economic agreement on a linked issue, e.g. trade for example.
- A final strategy involves transfers from gainers to losers or a redistribution of net benefits.

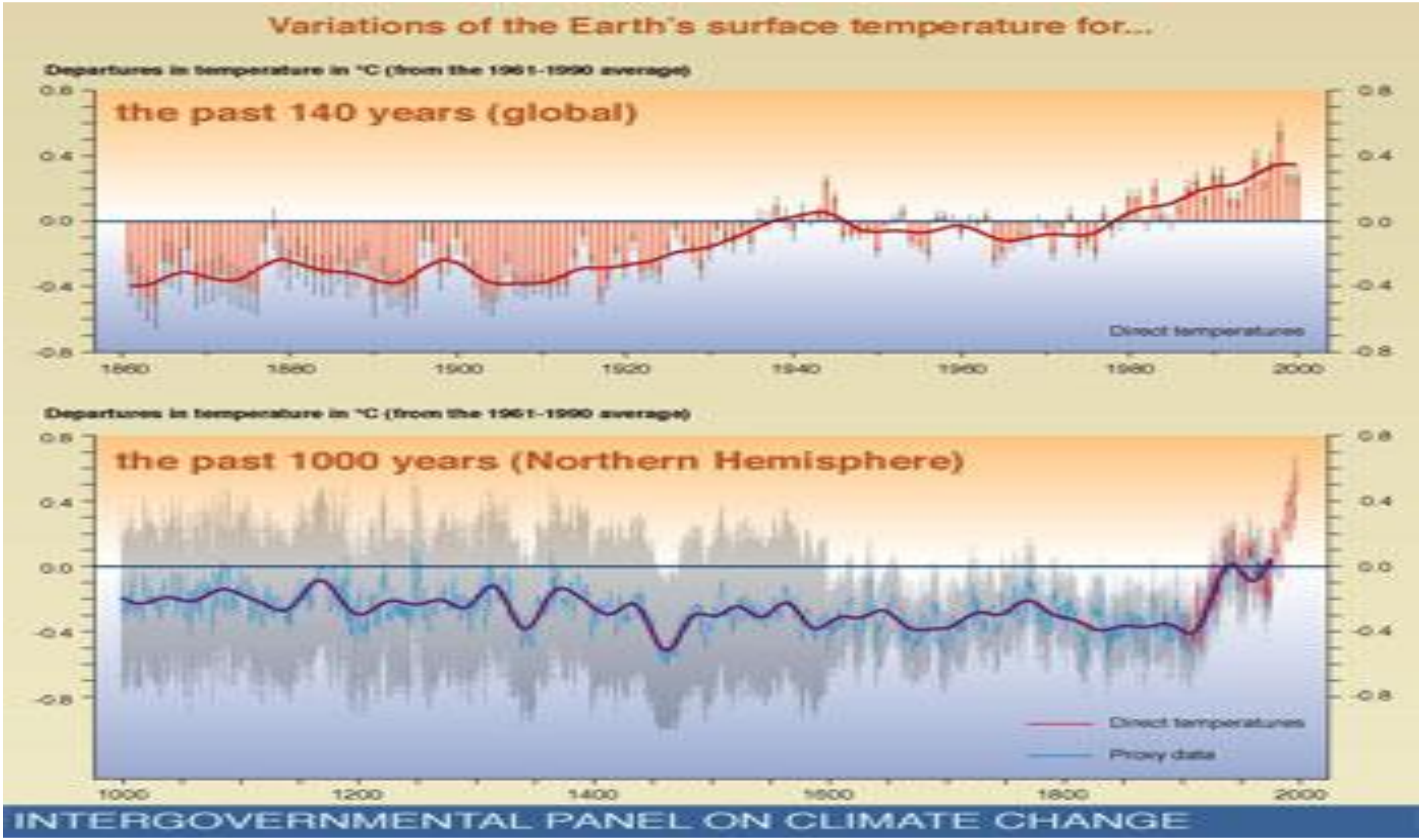
Carbon Emissions and Global Temp







Global Warming?



Global Warming Skeptic Questions

- Do our views regarding global warming become biased because we look at only certain locations, states, countries, etc.?
- Do we have an actual global temperature? If so, is it accurate?
- What are the economic costs of government action on this issue if global warming is not occurring? If it is occurring, can we stop it and should we?
- How do we not know that the current temperature is too cool, perfect, or too warm? Accurate temperature data only goes back to the 1850s, therefore any temps before then are estimates, so how do we know these estimates are accurate?
- If these estimates are accurate, they indicate that there was a significant period of global cooling, so shouldn't we expect the earth's surface to warm and revert to mean?
- Many species went extinct due to global cooling and government action was requested then, particularly during the 1980s, but now with global warming everyone is up in arms over something that may not be accurately measured, caused by humans (natural cycles), or something to worry about.

Global Warming Skeptic Questions

- If these are correct, should government still intervene?
  - Should we act today to avoid potential environmental issues?: Precautionary Principle (used by the EPA to make regulations)
  - Devise policies that maintain order during stronger storms
  - Implement plans that will provide better stability in communities after destructive natural disasters
- Is more government the solution?
  - *Robust Political Economy* by Mark Pennington
  - *Cool it* by Bjorn Lomborg