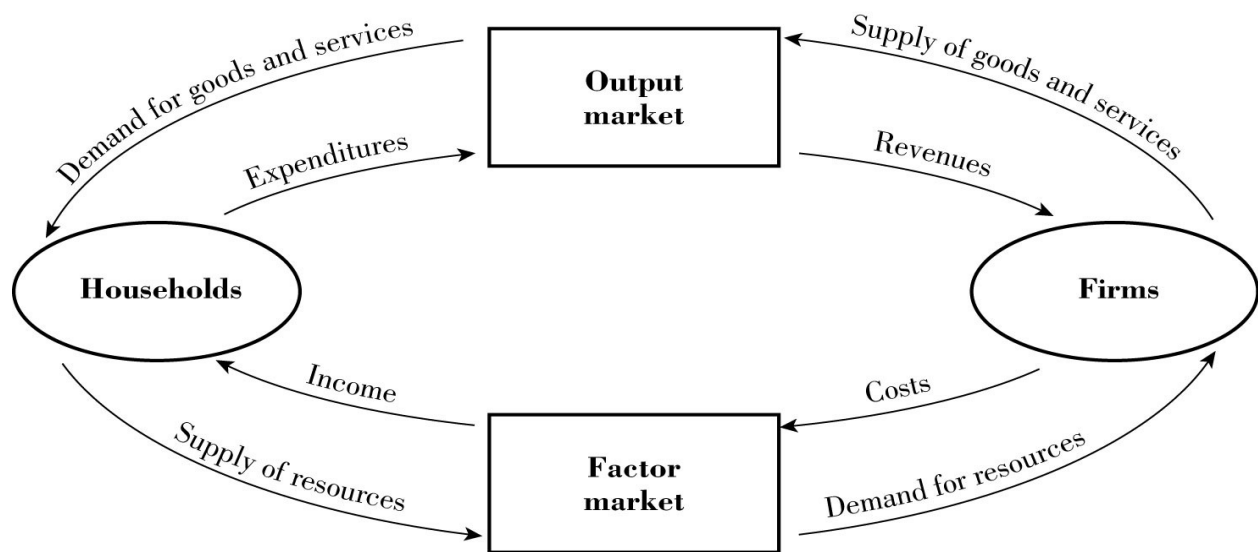


EC238 Exam Notes 2013

Chapter 1

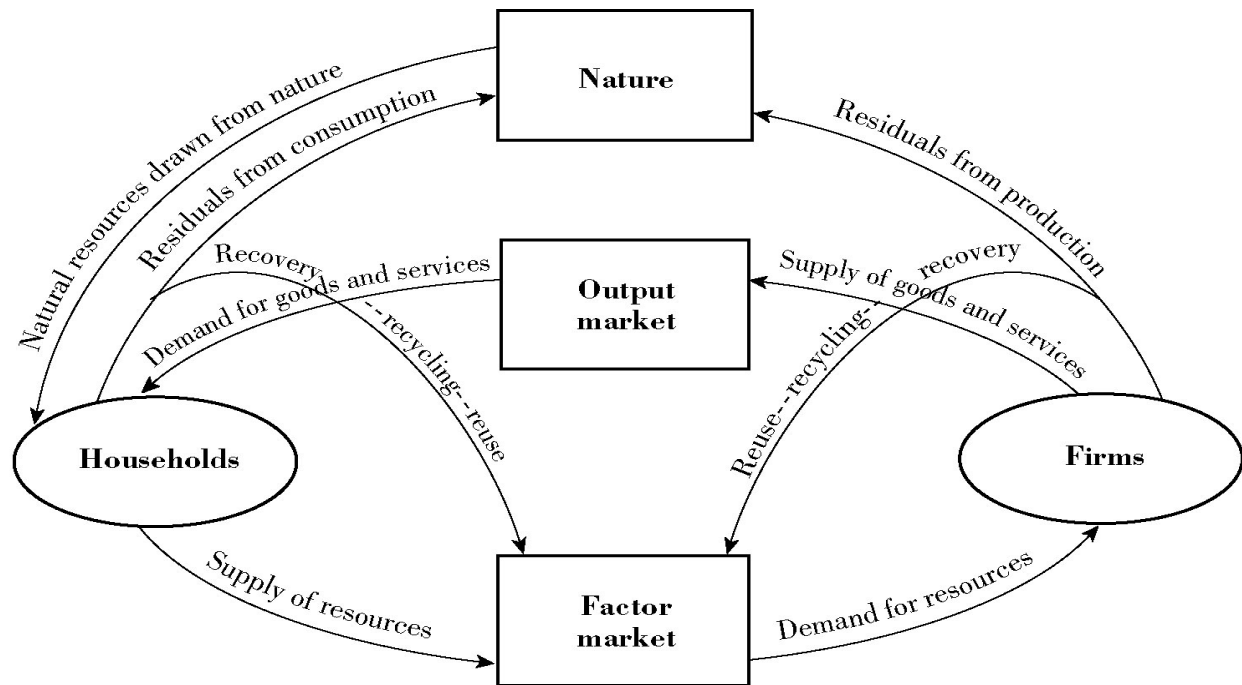
Circular Flow Model – illustrates the real and monetary flows of economic activity through the factor market and the output market

*Real flow runs counter clockwise, Monetary flow runs clockwise



Materials Balance Model – positions the circular flow within a larger schematic to show the connections between economic decision making and the natural environment

- Flow of resources *from* the environment *to* the economy
 - The focus of **Natural Resource Economics**
- Flow of residuals *from* the economy *to* the environment
 - The focus of **Environmental Economics**



- The flow of resources and residuals are balanced according to laws of science
- **First Law of Thermodynamics**
 - Matter and energy can neither be created nor destroyed
- **Second Law of Thermodynamics**
 - Nature's capacity to convert matter and energy is not without bound

Residual – the amount of a pollutant remaining in the environment after a natural or technological process had occurred

Assimilative capacity – the capacity of a residual to be absorbed naturally in the environment (e.g. carbon)

Causes of Environmental Damage

- Natural Pollutants arise from nonartificial processes in nature
 - e.g., ocean salt spray, pollen
- Anthropogenic Pollutants are human induced and include all residuals associated with consumption and production
 - e.g., chemical wastes, gases from combustion
 - Of greater concern to environmental economists

Sources of Pollution

- Sources grouped by mobility
 - Stationary Sources: fixed-site
 - Mobile Source: any nonstationary source
- Sources grouped by identifiability
 - Point source: single identifiable source
 - Nonpoint Source: a source that cannot be accurately identified, degrading in a diffuse way

Scope of Environmental Damage

- Local Pollution
 - Damage not far from the source
 - e.g., urban smog
- Regional Pollution
 - Damage extends well beyond the source
 - e.g., acidic deposition
- Global Pollution
 - Involving widespread environmental effects with global implications
 - e.g., global warming, ozone depletion

Environmental Objectives

- **Environmental Quality** – reduction in anthropogenic contamination to socially acceptable levels
- **Sustainable Development** – management of resources to ensure long-term quality and abundance
- **Biodiversity** – assuring the variety of distinct species, genetic variability, and variety of inhabitable ecosystems

National Environmental Policy Act (NEPA) of 1969

- Directs the integration of effort across agencies, executive departments, and branches of government in the U.S.
- Guides U.S. federal environmental policy
- Requires that environmental impact of public policy proposals be addressed

- Calls for an [Environmental Impact Statement \(EIS\)](#) on proposals or major federal actions

Risk Analysis - Chief Tool Guiding Policy Planning

- Two decision-making procedures
 - Risk Assessment – qualitative and quantitative evaluation of risk posed by an environmental hazard
 - Risk Management – decision-making process of choosing from alternative responses to environmental risk

Risk Management - Policy Evaluation Criteria

- Economic Criteria
 - Allocative Efficiency – requires resources to be appropriated such that additional benefits equal additional costs
 - Cost-effectiveness – requires that the least amount of resources be used to achieve an objective
- Equity Criterion
 - [Environmental Justice](#) – concerned with the fairness of the environmental risk burden across segments of society or geographic region

Risk Assessment – qualitative and quantitative evaluation of the risk posed to health or the ecology by an environmental hazard

Government Policy Approach

- **Command-and-Control Approach** – regulates polluters through the use of rules
 - E.g. set max pollution or set a certain abatement technology
- **Market Approach** – incentive-based policy that encourages conservation or pollution reduction
 - Can follow the “polluter-pays principle” whereby the polluter pays for the damage caused

Setting the Time Horizon

- Management Strategies – short-term strategies intended to manage an existing problem
 - An ameliorative intent
- Pollution Prevention (P2) – a long-term strategy aimed at reducing the amount or toxicity of residuals released to nature
 - A preventive intent

Chapter 2

- Defining the Relevant Market
 - A market refers to the interaction between consumers and producers to exchange a well-defined commodity
 - Defining the market context is one of the more critical steps in economic analysis
- Specifying the Market Model
 - The form of the model varies with the objective of the prospective study and its level of complexity

Demand(added vertically if more than 1)

- Demand refers to quantities of a good consumers are willing and able to buy at a set of prices during some time period, *ceteris paribus* (*c.p.*)
 - The willingness to pay (WTP), or demand price, measures the marginal benefit (MB) from consuming another unit of the good
- Law of Demand says there is an inverse relationship between price (P) and quantity demanded (Qd) of a good, *c.p.*
- Economic variables held constant when specifying demand include income, wealth, prices of related goods, preferences, and price expectations
- Market demand captures the decisions of all consumers willing and able to purchase a good
 - For a private good, market demand is found by *horizontally summing* individual demands

Supply(added vertically if more than 1)

- Supply refers to the quantities of a good the producer is willing and able to bring to market at a given set of prices during some time period, *c.p.*
- Law of Supply says there is a direct relationship between price (P) and quantity supplied (Qs) of a good, *c.p.*
 - Rising marginal cost (MC) supports this positive relationship
- Economic variables held constant when deriving a supply curve include production technology, input prices, taxes and subsidies, and price expectations
- Market Supply captures the combined decisions of all producers in a given industry
 - Derived by *horizontally summing* the individual supply functions

Market Equilibrium(set demand and supply P functions equal and solve)

- Supply and demand together determine a unique equilibrium price (P_E) and equilibrium quantity (Q_E), at which point there is no tendency for change
 - P_E arises where $Q_D = Q_S$
- Model for bottled water
 - D: $P = -0.01Q_D + 11.5$
 - S: $P = 0.0025Q_S + 0.25$
 - Equilibrium found where
 - $-0.01Q_D + 11.5 = 0.0025Q_S + 0.25$, or
 - where $Q_E = 900$ and $P_E = \$2.50$

Market Adjustment to Equilibrium

- Disequilibrium occurs if the prevailing market price is at some level other than the equilibrium level
 - If actual price is *below* its equilibrium level, there will be a shortage
 - **Shortage**: excess demand of a commodity equal to $(Q_D - Q_S)$
 - If actual price is *above* its equilibrium level, there will be a surplus
 - **Surplus** – excess supply of a commodity equal to $(Q_S - Q_D)$
- Price movements serve as a signal that a shortage or surplus exists, whereas price stability suggests equilibrium

Allocative Efficiency

- At the market level, allocative efficiency requires that resources be appropriated such that additional benefits to society are equal to additional costs incurred, or that $MB = MC$
 - The value society places on the good is equivalent to the value of the resources given up to produce it
- At the firm level, this efficiency is achieved at a competitive market equilibrium, assuming firms are profit maximizers
 - We illustrate by analyzing profit maximization

Marginal Revenue(MR) is the change in total revenue(TR) associated with a change in output(q), or

$$MR = \Delta TR / \Delta q$$

Marginal Cost(MC) is the change in total costs(TC) associated with a change in output (q), or

$$MC = \Delta TC / \Delta q$$

Marginal Profit(M π) is the change in total profit(π) associated with a change in output(q), or

$$M\pi = \Delta\pi / \Delta q$$

Profit Maximization

- Total profit (π) = Total Revenue (TR) - Total Costs (TC)
 - $TR = P \times Q$
 - TC is all economic costs, explicit and implicit
- Profit is maximized where the relative benefits and costs of producing another unit of output are equal
 - From the firm's perspective, benefit is measured by TR and costs are measured by TC
 - Profit is maximized where $DTR/DQ = DTC/DQ$, or where $MR = MC$, or where $M\pi = 0$
 - $MR = DTR/DQ$, additional revenue from producing another unit of Q
 - $MC = DTC/DQ$, additional cost from producing another unit of Q
 - $M\pi = MR - MC$, additional profit from producing another unit of Q
- In competitive industries, firms face constant prices determined by the market, which means $P = MR$
- Therefore the competitive market equilibrium achieves allocative efficiency because:
 - p maximization requires: $MR = MC$
 - Competitive markets imply: $P = MR$
 - So p maximization in competition means: $P = MC$, which defines allocative efficiency

Technical Efficiency

- Technical Efficiency refers to production decisions generate maximum output given some stock of resources
 - Preserves the stock of natural resources and minimizes subsequent generation of residuals linked to resource use
- Market forces can achieve technical efficiency so long competitive conditions prevail

Bottled Water market
Equilibrium is where
profit is maximized

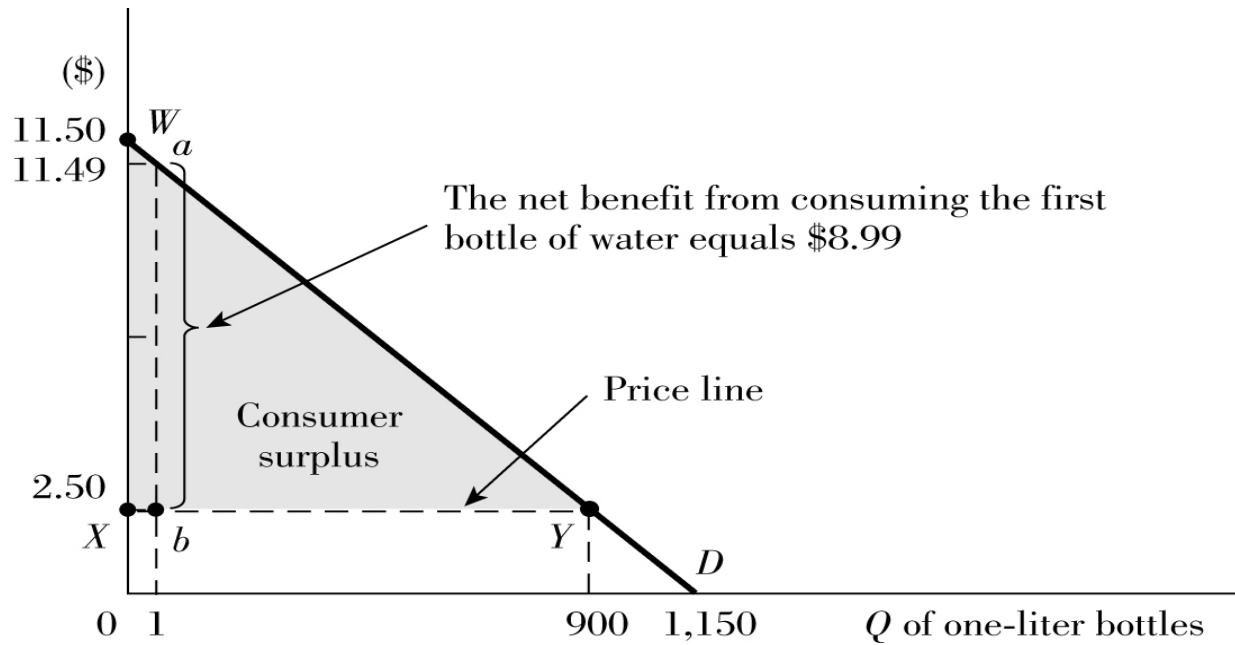
that

as

- Competitive firms must minimize costs to remain viable in the market because they cannot raise price to cover the added cost of inefficient production

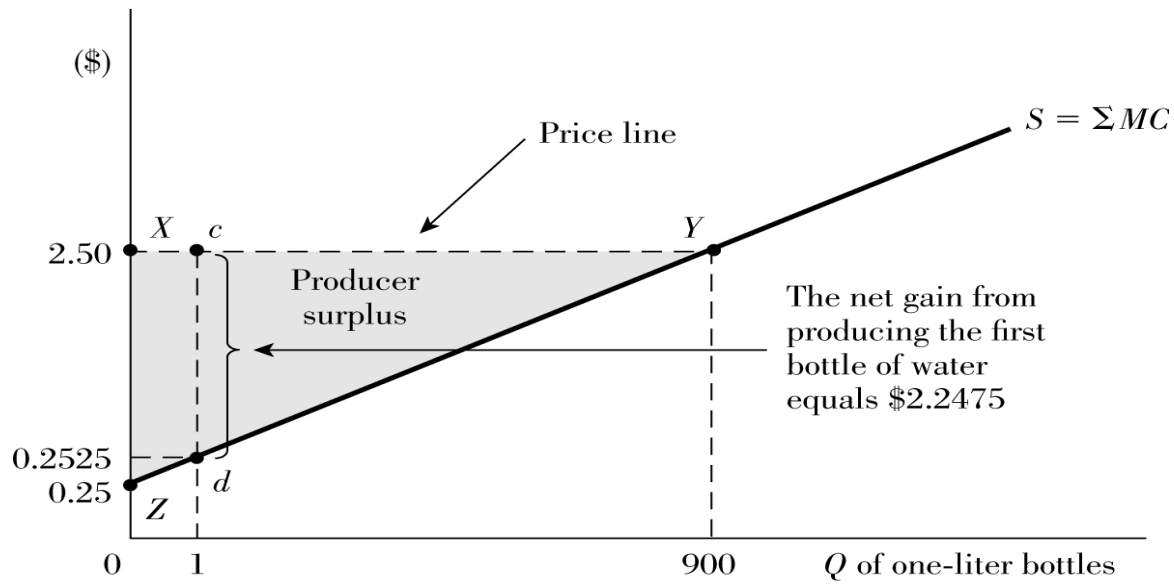
Welfare Measures - Consumer Surplus (CS)

- Consumer surplus is the net benefit to buyers estimated by the excess of marginal benefit (MB) of consumption over market price (P), aggregated over all units purchased
- Graphically measured as the triangular area above the price and below the demand curve up to the quantity sold



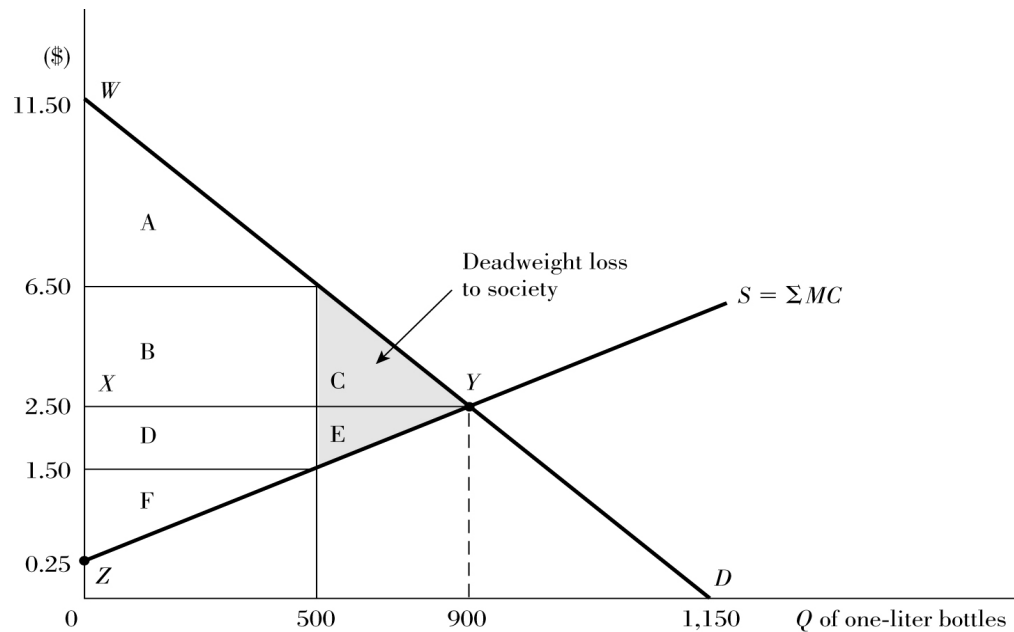
Welfare Measures - Producer Surplus (PS)

- Producer surplus is the net gain to sellers of a good estimated by the excess of the market price (P) over marginal cost (MC), aggregated over all units sold
- Graphically measured as the triangular area above the MC curve up to the price level over all units sold



Deadweight Loss (DWL)

- Society's welfare can be captured through the sum of Consumer Surplus and Producer Surplus
- Comparing these measures before and after a market disturbance helps quantify how society is affected by that disturbance through Deadweight Loss (DWL)
- DWL is the net loss of consumer and producer surplus due to an allocatively inefficient market event



Chapter 3

Environmental Pollution - A Market Failure

- Market failure is the result of an inefficient market condition
- Environmental problems are modeled as market failures using either the theory of public goods or the theory of externalities
 - If the market is defined as “environmental quality,” then the source of the market failure is that environmental quality is a public good
 - If the market is defined as the good whose production or consumption generates environmental damage, then the market failure is due to an externality

Environmental Quality - A Public Good

- A public good is a commodity that is nonrival in consumption and yields nonexcludable benefits
 - **Nonrivalness** – the characteristic of indivisible benefits of consumption such that one person’s consumption does not preclude that of another
 - **Nonexcludability** – the characteristic that makes it impossible to prevent others from sharing in the benefits of consumption
- Public goods generate a market failure because the nonrivalness and nonexcludability characteristics prevent market incentives from achieving allocative efficiency

- Achieving allocative efficiency in a public goods market depends on the existence of well-defined supply and demand functions
 - But the public goods definition disallows the conventional derivation of market demand

Market Demand for a Public Good

- In theory, market D for a public good is found by *vertically summing* individual demands
 - Vertical sum because we must ask consumers “*What price would you be willing to pay for each quantity of the public good?*”
- But consumers are unwilling to reveal their WTP because they can share in consuming the public good even when purchased by someone else (**nonrevelation of preferences**)
 - Due to the nonrival and nonexcludability characteristics
- This problem is called nonrevelation of preferences, which arises due to free-ridership (rational consumer realizes that the benefits of consumption are accessible without paying for them)
- Consequently, allocative efficiency cannot be achieved without third-party intervention

Solution to Public Goods Dilemma - Government Intervention

- Government might respond through *direct provision of public goods*
- Government might use *political procedures and voting rules* to identifying society's preferences about public goods

Environmental Problems - A Negative Externality

- An **externality** is a spillover effect associated with production or consumption that extends to a third party outside the market
 - Negative externality – an external effect that generates costs to a third party
 - Positive externality – an external effect that generates benefits to a third party

Relationship Between Public Goods and Externalities

- Although public goods and externalities are not the same concept, they are closely related
 - If the externality affects a broad segment of society and if its effects are nonrival and nonexcludable, the externality is itself a public good
 - If the externality affects a narrower group of individuals or firms, those effects are more properly modeled as an externality

Modeling a Negative Environmental Externality

- Define the market as refined petroleum
 - Assume the market is competitive
 - Supply is the marginal *private* cost (MPC)
 - Demand is the marginal *private* benefit (MPB)
 - Production generates pollution, modeled as a marginal *external* cost (MEC)
- **Problem:** Producers (refineries) have no incentive to consider the externality
- **Result:** Competitive solution is inefficient

Finding a Competitive Solution - Refined Petroleum Market (text example)

- S: $P = 10.0 + 0.075Q$
- D: $P = 42.0 - 0.125Q$, where
Q is thousands of barrels per day
- Since S is MPC and D is MPB, rewrite as:

$$\text{MPC} = 10.0 + 0.075Q$$

$$\text{MPB} = 42.0 - 0.125Q$$

- Set MPB = MPC

$$42.0 - 0.125Q = 10.0 + 0.075Q$$

- Solve:

$$Q_c = 160 \text{ thousand} \quad P_c = \$22 \text{ per barrel}$$

- Analysis:
 - This ignores external costs from contamination
 - Allocative efficiency requires P to equal *all* MC
 - MPC undervalues opportunity costs of production; Q_c is too high; P_c is too low

Finding an Efficient Solution - Refined Petroleum Market

- Let Marginal External Cost (MEC) = $0.05Q$
- Marginal Social Cost (MSC) = MPC + MEC
 - $\text{MSC} = 10.0 + 0.075Q + 0.05Q$
= $10.0 + 0.125Q$
- Marginal Social Benefit (MSB) = MPB + MEB

- Assuming no external benefits, $MEB = 0$, so $MSB = MPB$
- Set $MSC = MSB$
 - $10.0 + 0.125Q = 42.0 - 0.125Q$
 - Solving: $Q_E = 128$ thousand $P_E = \$26/\text{barrel}$
- Observe: In the presence of an externality, market forces *cannot* determine an efficient outcome

Comparing the Equilibria - Using M_p and MEC

- Competitive firm maximizes p where
 - $MPB = MPC$, or where $MPB - MPC = 0$, or
 - $M_p = 0$
 - since $MPB - MPC = M_p$ by definition
- Efficient firm produces where
 - $MSB = MSC$ or $MPB + MEB = MPC + MEC$
 - or $MPB - MPC = MEC$, if $MEB = 0$, so...
 - $M_p = MEC$

Example

- $M_p = MPB - MPC$
 $= (42 - 0.125Q) - (10 + 0.075Q)$ so
- $M_p = 32 - 0.2Q$
- $MEC = 0.05Q$
- Find the competitive and efficient equilibria using these equations
- Competitive solution
 - Set $M_p = 0$, or $32 - 0.2Q = 0$, so $Q_C = 160$
 - Find P by substituting into MPB or MPC

Results of negative externality

Q_C is too high, i.e., overallocation of resources

P_C is too low, since MEC is not captured by market transaction

□ Using MPB, $P_C = 42 - 0.125(160) = 22$

■ Efficient solution

■ Set $M_p = MEC$, or $32 - 0.2Q = 0.05Q$, so $Q_E = 128$

■ Find P by substituting into MPB or MPC

□ Using MPB, $P_E = 42 - 0.125(128) = 26$

Measuring Society's Net Gain - From Restoring Efficiency

- As Q falls from 160 to 128:
 - Refineries lose p measured as M_p (or excess of MPB over MPC) for each unit of Q contracted
 - Defines area **WYZ**
 - Society gains accumulated reduction in MEC for each unit of Q contracted
 - Defines area **WXYZ**
- Net gain = Area WXYZ - Area WYZ = Area WXY

Analysis

- $Q_C = 160$ thousand
 - At this point, $MEC = \$8.00$ per barrel
 - Note $M_p \neq MEC \Rightarrow$ not efficient
- $Q_E = 128$ thousand
 - At this point, $MEC = M_p = \$6.40$ per barrel
- Efficiency would improve if output were restricted by 32 thousand (i.e., $160 - 128$)

Property Rights

- Valid claims to a good or resource that permit the use and transfer of ownership through sale
- For environmental goods, it's unclear who "owns" rights
- Economics says it's the *absence* of rights that matters, not who possesses them

Coase Theorem

- Proper assignment of property rights, even if externalities are present, will allow bargaining between parties such that efficient solution results, regardless of who holds rights

Important Observations

- Both externality and public goods models show inefficiency of private market solution, i.e., market failure
- Underlying source of failure is **absence of property rights**

- Assumes costless transactions
- Assumes damages are accessible and measurable

Bargaining When Rights Belong to Refineries

- Recreational users are willing to pay (WTP) refineries for each unit of Q not produced
 - Will pay *up to* the negative effect on utility (MEC)
- Refineries are willing to accept payment not to produce
 - Will accept payment *greater than* their loss in profit from contracting production (M_p)
- Initial point is Q_c , since the refineries, who own the rights, would choose this point

- Recreational users:
 - Willing to offer a payment r
 - $r < (MSC - MPC)$, or $r < MEC$
- Refineries:
 - Willing to accept payment r
 - $r > (MPB - MPC)$, or $r > M_p$
- Bargaining should continue as long as:

$(MSC - MPC) > r > (MPB - MPC)$ or

$MEC > r > M_p$

- At Q_c : Refineries' $M_p = 0$, but $MEC > 0$, (distance XY)
 - Since $MEC > M_p$, bargaining begins
- Between Q_c and Q_E , same condition holds
- At Q_E : $MEC = M_p$, (distance WZ); output reductions beyond this point are infeasible, since $M_p > MEC$

Bargaining When Rights Belong to Recreational Users

- Bargaining will proceed analogously
- An efficient outcome can be realized without government intervention
- Limitations of the Coase Theorem
 - Assumes costless transactions and measurable damages

- At minimum it must be the case that very few individuals are involved on each side of the market

Common Property Resources - Property Rights Poorly Defined

- **Common Property Resources** are those for which property rights are shared
- Because property rights extend to more than one individual, they are not as clearly defined as for pure private goods
- Problem is that public access without any control leads to exploitation, which in turn generates a negative externality
- Internalize externality by:
 - Assigning property rights, OR
 - Set policy prescription, such as:
 - Set standards on pollution allowed
 - Tax polluter equal to MEC at Q_E
 - Establish a market and price for pollution

Chapter 4

Types of Environmental Standards

Ambient standard – a standard that designates the quality of the environment to be achieved, typically expressed as a maximum allowable pollutant concentration

- **Technology-based standard** – a standard that designates the equipment or method to be used to achieve some abatement level
- **Performance-based standard** – a standard that specifies a pollution limit to be achieved but does not stipulate the technology

Implications of Using Standards

- Two key implications
- Are standards set to achieve allocative efficiency?
 - where MSB of abatement equals MSC of abatement
- Given some environmental objective, is that objective being achieved in a manner that is cost-effective?

*Efficient Standard ~ $MSB_{Abatement} = MSC_{Abatement}$

MSB of Abatement

- Additional social gains as pollution abatement increases
- Measured as reduction in damages or costs caused by pollution (i.e., reduction in MEC)
- Represents society's D for environmental quality
 - Implies MSB is *negatively* sloped

MSC of Abatement

- Sum of all polluters marginal abatement costs plus government's marginal cost of enforcement
- Two components: $MSC = MAC_{MKT} + MCE$
 - MAC_{MKT} is the sum of all polluters' individual marginal abatement cost (MAC) functions
 - $SMAC_i = MAC_{MKT}$
 - MCE is marginal cost of [enforcement](#)
 - Change in government's cost of monitoring and enforcing abatement
- MSC is *positively* sloped

Firm-Level MAC

- Measures the change in cost from reducing pollution, using least-cost method
 - Equals *forgone Mp* if the least-cost abatement method is to reduce output
- Typically positively sloped and increasing at increasing rate
 - For simplicity, it is usually assumed that MAC is linear



- Legislative Constraints
 - Many standards are benefit-based, i.e., set to improve society's well-being with no consideration for the associated cost
- Imperfect information
 - Inability to identify MSB and/or MSC
 - MSB: due to the problem of nonrevelation of preferences

- MSC: difficulty in identifying each firm's MAC, including implicit costs
- Nonuniformity of pollutants
 - Changes in emissions do not have uniform effects on environment
 - e.g., if polluters are at different distances from populations or ecosystems, MSB would vary
- Regional differences
 - Even if A_E is identified at the *national* level, it is not likely to be efficient at *regional* level
- If allocatively efficient standards are unlikely, we use cost-effectiveness to evaluate how standards are implemented
- Cost-effectiveness depends on the approach
 - Command-and-control: using standards or rules to *control* pollution
 - Market: using incentives and market forces to *motivate or encourage* abatement and conservation

Modeling Regional Differences

- Consider two regions, X and Y, with same MSC of abatement
- Suppose their MSB of abatement curves differ, such that $MSB_X < MSB_Y$
- Result: Allocatively efficient level of abatement for region X (A_X) would be *lower* than for region Y (A_Y)

Command-and-Control (CAC) – Assessing Cost-Effectiveness

Technology-based standard

- **Technology-based standards** specify the type of abatement equipment or method to be used
- By definition, these standards potentially **prevent** firms from selecting and using the least-cost abatement method

Analysis: Use the MAC Curve

- Technology-based standard
 - If prevented from using the least-cost abatement method, firms would operate above their MAC curve
- Performance-based standard
 - If allowed to select an abatement method to achieve some performance level, p-maximizing firms will choose the least-cost method and operate on the MAC curve

Uniform standard

| |
|---------------------------|
| Technology-based standard |
|---------------------------|

| |
|-------------------------------|
| standards resources abatement |
|-------------------------------|

| |
|---|
| <u>Modeling Cost-Ineffectiveness</u> |
|---|

- Uniform waste economic as long as costs differ among polluting sources
- Cost savings can be obtained if low-cost abaters do more cleaning up than high-cost abaters
- Let's prove this by building a model of 2 hypothetical firms
- Find the total abatement costs using the uniform standard
- Solution:
- The TACs for each firm are
 - $TAC_1 = 1.25(A_1)^2 = 1.25(5)^2 = \31.25
 - $TAC_2 = 0.3125(A_2)^2 = 0.3125(5)^2 = \7.81
 - Sum of TACs = **\$39.06**, which represents the value of resources given up by society to clean up the pollution
- Use MACs to prove that the uniform standard is not cost-effective
- Solution
 - o With uniform standards, the MACs are not equal
 - $MAC_1 = 2.5(5) = \$12.50$
 - $MAC_2 = 0.625(5) = \$3.125$
 - Shows that Polluter 2 has a cost advantage
 - The 5th unit of A (i.e., the marginal unit) costs Polluter 2 \$9.37 less than it costs Polluter 1
 - o It would be cheaper if Polluter 2 did more of the abating, but it lacks an incentive to do so
- Find the cost-effective abatement, A_1 and A_2
- Solution: uses 3 simple steps
 - (i) Set $MAC_1 = MAC_2$

$$2.5A_1 = 0.625A_2$$

An application of the equimarginal principle of optimality

(ii) Set $A_1 + A_2 = \text{Abatement Standard}$

$$A_1 + A_2 = 10$$

(iii) Solve equations (i) and (ii) simultaneously

$$2.5(10 - A_2) = 0.625A_2$$

$$25 - 2.5A_2 = 0.625A_2, \text{ so } A_1 = 2 \quad A_2 = 8$$

- Prove that this is cost-effective

$$MAC_1 = 2.5A_1 = 2.5(2) = \$5.00$$

$$MAC_2 = 0.625A_2 = 0.625(8) = \$5.00$$

- Show that total abatement costs are lower at this abatement allocation than the costs when a uniform standard is used

- Solution

- $TAC_1 = 1.25(2)^2 = \$5.00$

- $TAC_2 = 0.3125(8)^2 = \$20.00$

- S TACs (cost-effective) = \$25.00

- S TACs (uniform standard) = \$39.06

- Cost Savings = $(\$39.06 - \$25.00) = \$14.06$

- Problem: Public officials will **not** know where to set firm-specific standards without knowing MAC for every polluter

- Implies that a cost-effective solution is virtually impossible under CAC framework

- Result is possible using market approach

Chapter 5

- Market approach refers to incentive-based policy that encourages conservative practices or pollution reduction strategies

- Difference between market approach and command-and-control approach is *how* each approach attempts to achieve its objectives

- Types of Market Instruments

- Pollution charge
- Subsidies
- Deposit/refund systems
- Pollution permit trading systems

Pollution Charge

- Fee that varies with amount of pollutants released
 - Based on “Polluter-Pays Principle”
- Types of pollution charges
 - **Effluent/emission fees**
 - A fee imposed directly on the discharge of **pollution**
 - Assigns a price to pollution
 - Typically implemented through a tax

SINGLE POLLUTER CASE

MULTIPLE POLLUTER CASE

ASSESSING THE MODEL (PROS)

- Abatement standard is met
- Generates \$40 in tax revenues from high-cost abater and \$10 from low-cost abater
- Low-cost abaters do most of cleaning up
- Cost-effective solution is obtained
 - MACs are equal at \$5 tax rate
 - Combined TAC of \$25 is lower than \$39.06 under command-and-control with a uniform standard

Assessing the Model (cons)

- Tax authority will not know where MACs are equal
 - o Will have to adjust rate until objective achieved
- Monitoring costs potentially higher

- Firms might evade tax by illegally disposing pollutants
- Distributional implications
 - Consumers may pay higher prices due to tax
 - Job losses may result from polluter paying new taxes and/or changing technology to abate

■ Product charge

- Fee added to price of pollution-generating **product**, which generates negative externality
- Impose product charge as per unit tax on product, e.g., gas tax
 - How does the tax on gasoline in the US compare with that of other nations?
 - If the tax equals the marginal external cost (MEC) at Q_E , it is called a **Pigouvian tax**

■ User charge

■ Administrative charge

Environmental Subsidies

■ Two major types of subsidies:

■ **Abatement equipment subsidies**

- Defined as a payment aimed at lowering the cost of abatement technology
 - Goal is to internalize the positive externality associated with the consumption of abatement activities
- If the subsidy (s) equals the marginal external benefit (MEB) at Q_E , it achieves an efficient equilibrium and is called a **Pigouvian subsidy**

- It is difficult to measure the MEB

- May bias polluters' decisions about how best to abate

■ **Pollution reduction subsidies**

Assessing the Model

- In theory, achieves an efficient outcome
- In practice, difficult to identify the value of MEC at Q_E
- Allows only for an output reduction to reduce pollution

Pigouvian Subsidy - Market for Scrubbers

- To implement, government pays the polluter a subsidy (s) for every unit of pollution abated below some pre-established level Z_{ST}
- Per unit subsidy = $s(Z_{ST} - Z_o)$, where Z_o is the actual level of pollution
 - Analogous to an emission charge
 - *Might be less disruptive than an equipment subsidy*
 - *Can have the perverse effect of elevating pollution levels in the aggregate since the subsidy lowers unit costs and raises profit, encouraging entry*

Deposit/Refund Systems

- A deposit/refund system is a market instrument that imposes an up-front charge to pay for potential damages and refunds it for returning a product for proper disposal or recycling
- Targets the *potential* vs. actual polluter
- The deposit is intended to capture the MEC of improper waste disposal (IW) *in advance*
 - *Preventive* vs. ameliorative

Modeling Deposit/Refund System - IW disposal market

- MEC_{IW} : health damages + aesthetic impairment from litter, trash accumulation, etc.
- MPC_{IW} : costs to disposer (e.g., trash receptacles, collection fees, plus forgone revenue from not recycling)
- $MSC_{IW} = MPC_{IW} + MEC_{IW}$
- MPB_{IW} : demand for improper disposal
 - Assume $MEB_{IW} = 0$, so $MPB_{IW} = MSB_{IW}$

Pollution Permit Trading Systems

- A pollution permit trading system establishes a market for rights to pollute by issuing tradeable pollution credits or allowances
 - **Credits** are issued for emitting *below* a standard
 - **Allowances** indicate how much can be released
- Two components of the system are
 - Fixed number of permits is issued based on an “acceptable” level of pollution set by government

Assessing the Model

- Promotes responsible behavior
- Requires minimal supervision by government
- Can help slow the use of virgin raw materials by improving availability of recycled materials

- The permits are marketable
- Bargaining gives rise to a market for pollution rights

How Permit Trading Works

- There is an incentive to trade as long as polluters face different MAC levels
- Suppose a firm has 50 permits but normally emits 75 units of SO₂. What must it do?
 - o Answer
 - Abate 25 units of emissions OR
 - Buy 25 permits from another producer
- Which option will the firm choose?
 - o Answer
 - Whichever option is cheaper

Result

- Low-cost abaters will clean up pollution and sell excess permits to other firms
 - o They will sell at any P higher than their MAC
- High-cost abaters will buy permits rather than abate
 - o They will buy at any P lower than their MAC
- Trading will continue until the incentive to do so no longer exists, at which point, the cost-effective solution is obtained, i.e., the MACs across firms are equal
- Trading establishes the price of a right to pollute without government trying to “search” for a price
- No tax revenues are generated
- Trading system is flexible
 - o Note that an emissions standard can be adjusted by changing the number of permits issued

Chapter 6

- Risk is the chance of something bad happening
- Dealing with risk involves two tasks:
 - Identifying the degree of risk

- Responding to it
- Policy is a formal response to social risk
 - Policymakers must use a systematic risk assessment before devising a policy response
- Classifying risk
 - **Voluntary risk:** deliberately assumed at an individual level
 - **Involuntary risk:** not the result of willful decision
 - Government tries to control society's exposure to some involuntary risks, e.g., chemical exposure
- Environmental risk is the involuntary risk of exposure to an environmental hazard
 - **Hazard:** source of environmental damage
 - **Exposure:** pathways between the hazard and the affected population or natural resource

Methods in Risk Analysis

- **Risk Assessment** refers to identifying risk
 - Qualitative and quantitative evaluation of risk of an environmental hazard to health or the environment
 - In the US, there is a [National Center for Environmental Assessment](#)
- **Risk Management:** responding to risk
 - Evaluating and selecting from among regulatory and nonregulatory risk responses

A MODEL OF HEALTH RISK ASSESSMENT

Hazard Identification

- Use of scientific data to determine if a "causal" relationship exists between the pollutant and adverse effects on health or the ecology
- 3 scientific methods to identify health hazards
 - Case cluster
 - A study based on the observation of an abnormal pattern of health effects in some population group
 - Animal bioassay

- A study based on comparative findings of lab experiments on living organisms before and after exposure to some hazard
- Epidemiology
 - A study of causes and distribution of disease in human populations based on characteristics like age, gender, occupation, etc.

Dose-Response Assessment

- Uses data from the hazard identification to devise a profile of the pollutant's effects
- The *dose-response* relationship gives the quantitative relationship between doses of the contaminant and corresponding reactions
- Key element is determining a threshold
 - A threshold is the level of exposure up to which no response exists

HYPOTHETICAL DOSE-RESPONSE FUNCTIONS

Risk Characterization

- A description of risk based upon an assessment of a hazard and exposure to that hazard
- Two elements:
 - Quantitatively identifies the magnitude of the risk and a way to compare one risk to another
 - Qualitatively gives context to the numerical risk value

Quantitative Component of Risk Characterization

- Can be measured using **probabilities**
 - some based on actuarial risks (using factual data)
 - number of victims relative to number exposed
 - some are inferred from animal bioassays or epidemiology studies
- Can be measured using a **reference dose (RfD)**
 - RfD is exposure to a hazard that can be tolerated over a lifetime without harm
 - milligrams of pollutant per body weight per day

Qualitative Component of Risk Characterization

- Comprises:
 - description of hazard
 - assessment of exposure and any susceptible groups
 - data used
 - scientific and statistical methods used
 - underlying assumptions
- Identifies scientific uncertainties, data gaps, measurement errors

EPA's IRIS

- Integrated Risk Information System
 - Repository of consensus views on health risks of environmental contaminants
 - Available to general public
 - Each summary includes:
 - risk assessment table (quantitative measures)
 - discussion of data used to form consensus
 - reference listing of studies

Ecological Risk Assessment

- Ecological risk assessment evaluates the probability of changes to the natural environment linked to such stressors as pollution exposure or climate change
 - e.g., crop damage, soil contamination
 - See the boxed Application on *Climate Change Ecological Risk Assessment*
- EPA has developed [guidelines](#) aimed specifically at ecological risk assessment
- Three phases of ecological risk assessment
 - Problem Formulation; Analysis; Risk Characterization

MODEL OF ECOLOGICAL RISK ASSESSMENT

Problem Formulation

- Identify the ecological entity that is potentially at risk is identified.

- Determine which characteristic of the entity may be at risk and the entity's overall importance or relevance
- Develop a model to show links between the ecological entity and the environmental stressor with an accompanying description

Analysis Phase

- Identifies information needed to predict ecological responses to environmental hazards under various exposure conditions
- Prepare calculations to quantify the risk
 - e.g., hazard quotient
 - ratio of a contaminant concentration to some benchmark
 - e.g., bioaccumulation rate
 - measures how pollutants are taken up by an ecological species.

Risk Characterization

- Description of risk based on information gathered from in previous phases
 - Provides degree of confidence in the risk estimates, evidence that supports the findings, and an interpretation of predicted ecological effects
 - Included are such risk descriptors as severity of the damage, time over which damage occurs, and extent of the damage in terms of numbers and types of species

Risk Management - Responding to Risk

- **Risk management** is the decision-making process of evaluating and choosing from alternative responses to environmental risk
- Two major tasks:
 - Determining what level of risk is "acceptable" to society
 - Evaluating and selecting the "best" policy instrument to achieve that risk level

Determining "Acceptable" Risk

- The extent of risk reduction determines the level of exposure and stringency of policy
 - Should exposure be set to 0? If not, what positive level is appropriate?
- Officials might use **de minimis risk** as baseline
- Might use **comparative risk analysis** to compare risk of environmental hazard to other risks faced by society

- e.g., risk of exposure to 4 pCi/l of radon compares to the risk of dying in a car crash

Selecting Policy Response

- Evaluates alternative policies capable of achieving “acceptable” risk level
- Selects “best” option
 - How? Uses risk management strategies

Risk Management Strategies

- Used to evaluate options in a systematic way
- Key considerations are
 - The level of risk established
 - The benefits to society from adopting the policy
 - The associated costs of implementing the policy
- Prevalent risk management strategies are
 - **Comparative risk analysis** is an evaluation of relative risk
 - Known as risk-risk analysis when used to select from alternative policy instruments
 - **Risk-benefit analysis** involves assessing the risks of a hazard along with the benefits to society of not regulating that hazard
 - **Benefit-cost analysis** uses the economic criterion of allocative efficiency, comparing the *MSB* of a risk reduction policy to the associated *MSC*
 - Supported by presidential executive orders, starting with President Reagan

Chapter 7

Environmental Benefits - Conceptual Issues

- Environmental benefits measure damage reductions
- Policy brings about *changes* in these damage reductions, and these changes are referred to as incremental benefits
 - Incremental benefits are the reduction in health, ecological, and property damages associated with an environmental policy initiative
 - See the boxed Application on incremental benefits of the European Union’s Climate Change Initiatives

Types of Incremental Benefits

- Primary environmental benefits
 - Damage-reducing effects that are a direct consequence of implementing environmental policy
- Secondary environmental benefits
 - Indirect gains to society that may arise from a stimulative effect of primary benefits or from a demand-induced effect to implement policy

Assign Value to Incremental Benefits

- Since environmental quality is a public, nonmarketed good, its D cannot be identified because of nonrevelation of preferences
- But if we could infer society's D (or MSB) for environmental quality, we could measure incremental benefits as follows:
 - o Area under MSB is TSB
 - o Changes in TSB would be incremental benefits

Modeling Incremental Benefits

- Find baseline TSB *before* policy
- Find new TSB *after* policy is implemented
- Subtract baseline from new TSB

MARGINAL SOCIAL BENEFIT
BENEFIT

TOTAL SOCIAL

Valuing Environmental Quality - Two Sources of Value

- Total value = User value + Existence value
 - User value is the benefit derived from physical use or access to an environmental good
 - Direct user value is the benefit derived from directly consuming services provided by an environmental good
 - Indirect user value is the benefit derived from indirect consumption of an environmental good
 - Existence value is the benefit received from the continuance of an environmental good
 - Motivated by vicarious consumption and stewardship

Approaches to Measuring Benefits

- **Physical linkage approach**
 - Estimates benefits based upon a *technical relationship* between environmental resource and user of resource
- **Behavioral linkage approach**
 - Estimates benefits using observations of behavior in *actual* markets or survey responses about *hypothetical* markets
- Physical Linkage
 - Damage Function Method
- Behavioral Linkage
 - Direct Methods
 - Political Referendum Method
 - Contingent Valuation Method
 - Indirect Methods
 - Averting Expenditure Method
 - Travel Cost Method
 - Hedonic Price Method

*see Table 7.2

Damage Function Method

- Specifies a relationship between a contaminant (C) and some observed total damage (TD)
- Estimates benefits as TD declines from the policy-induced change in C
 - Note: Dose-response function is one type of damage function

Applications of the Damage Function Method

- *Used for measuring a specific type of incremental benefit, as opposed to performing a comprehensive benefit assessment.*
- *It is usually used where market-determined prices are available to monetize the gain.*

Assessing the Damage Function Method

- Estimates only one type of incremental benefit at a time
- Represents only a first step, since it is not capable of simultaneously monetizing the damage reduction that it identifies

Example

- Suppose a U.S. policy reduces pollution damage to crops, resulting in a higher crop yield as an incremental benefit
 - Model as an increase in supply (S)
- Measure the incremental benefit as:
- **D(consumer surplus (CS) + producer surplus (PS))**

Contingent Valuation Method (CVM) – Direct Method under Behavioral Linkage Approach

- Estimates benefits from survey responses about WTP for environmental quality *contingent* upon hypothetical market
- Tries to finesse nonrevelation problem
- Steps:
 - Construct model of hypothetical market
 - Design survey
 - Assess honesty of respondents

Assessing the CVM

- Broad applicability
- Can capture existence as well as user value
- Inherent biases due to survey approach, such as an individual's unwillingness to reveal a WTP because of the free-ridership problem

Applications of CVM

- Estimation of the value of a statistical human life: \$3.2 million to \$8.0 million (\$2010).
- Estimation of society's WTP for water quality improvements.
- Smith and Desvousges (1986): \$60 (\$2010) per year to improve the Monongahela River from botable to fishable quality; average household in five western Pennsylvania counties.
- Carson and Mitchell (1988): nationwide survey; \$175 (\$2010) per year for water quality improvements.
- How can the difference be explained?

- The difference may be attributable to **existence value**.

Averting Expenditure Method (AEM) – Indirect Method under Behavioral Linkage Approach

- Estimates benefits as the reduction in spending on goods that are **substitutes** for a cleaner environment
 - As pollution damages the environment, people incur “averting” expenditures to improve their *personal* environment
 - This spending is reduced as policy improves the *overall* environment
- This spending reduction is an estimate of the WTP for associated incremental benefits

Modeling AEM

- Define overall environmental quality (E)
- The relevant market for study is personal environmental quality (X)
 - D is MB; S is MC or averting expenditures
 - MC_0 of X_0 is linked to a given level of E_0
 - As the overall environment improves, or as E increases from say, E_0 to E_1 , the individual incurs lower costs, so MC shifts right from MC_0 to MC_1 and X_0 improves to X_1
- Change in spending for the **same level of X** is an estimate of incremental benefits

Assessing the AEM

- Problem of jointness of production
 - Some AE yield benefits other than those from improving environmental quality
 - e.g., air conditioning provides comfort as well as filters the air
 - Hence, the benefit estimate can be biased

Applications of CVM

- Abrahams, Hubbell, and Jordan (2000) used the AEM to estimate the annual benefits to Georgia residents associated with safer drinking water.
- Measured changes in the residents' spending on bottled water and water filters.
- An individual's WTP: \$67 (\$2010) per year
- Total benefits to Georgia: \$495 million (\$2010)

Travel Cost Method - Indirect Method under Behavioral Linkage Approach

- Estimates benefits as an **increase in consumer surplus (CS)** in the market for a **complement** to environmental quality (i.e., recreational use), as policy improves that quality
- As policy improves the environment, the D for recreational use of the environment increases, causing an increase in CS
- This CS increase is the benefit estimate

Assessing the

Market is recreational services
of lake

TCM

- Estimates only user value
- Addresses only recreational use (i.e., not useful for estimating commercial benefits)
- Estimates are biased downward if access to site is congested

Applications of the TCM

- Because of its limitations, the TCM is commonly used to value improvements to water bodies used mainly for recreation.
- Consider the following results (WTP per person per day in 2010 dollars) from three independent analyses.
- Vaughan and Russell (1982): \$10.58 - \$21.17
- Smith and Devousges (1985):) 0.14 -\$67.61
- Smith, Desvousges, and McGivney (1983): \$2.35 -\$4.86
- The estimates tend to vary considerably.
- Reason: TCM estimates tend to be sensitive to the site under study.
- Demographic variables across regions can be controlled.
- But other site differences, such as aesthetics, access to major highways, and substitute recreational opportunities, are difficult to quantify and control.
- So, it is unlikely that TCM can determine a **generalized** value of improved water quality.

Hedonic Price Method (HPM) - Indirect Method under Behavioral Linkage Approach

- HPM is based on the theory that a good or service is valued for the attributes or characteristics it possesses.
- This perception of value suggests that implicit or hedonic price exist for product attributes, and these prices can be determined from the explicit price of the product.

- Uses estimated **hedonic**, or implicit, price of an environmental attribute to value a policy-driven improvement
 - e.g., $P_{\text{HOUSE}} = f(X_1, X_2, \dots, X_n, E)$, where:
 - each X_i is an attribute of the house, and E is the environmental quality in the area
- Hedonics uses regression analysis, which provides estimates of the prices of the individual attributes, including E
- This price could be used to estimate the D for environmental quality, which in turn could be used to measure the incremental benefit of improving that quality
- Recall that incremental benefit can be measured as an area under the D curve

Assessing the HPM

- Logical, intuitive
- Difficult to employ
- Requires complex empirical modeling
- Requires extensive data

Applications of the HPM

- Kohhase(1991) finds that housing prices in the Houston area are positively affected by the distance from a Superfund site up to 6.2 miles, specifically that each additional mile in distance adds \$4791 (\$2010) to a property's value.

Chapter 8

Environmental Costs - Conceptual Issues

- Incremental costs are the change in costs arising from an environmental policy initiative
- Economic costs include
 - Explicit (or monetary) costs
 - Implicit (or nonmonetary) costs
- Ideal measure is the social costs of policy
 - Expenditures needed to compensate society for resources used so that its utility level remains the same

Explicit Costs

- Administrative, monitoring, and enforcement expenses incurred by the public sector plus compliance costs incurred by all sectors

- Capital (or fixed) costs
 - spending on plant, equipment, construction, and process changes for pollution abatement
- Operating (or variable) costs
 - costs of operating and maintaining abatement processes

Implicit Costs

- value of nonmonetary effects that negatively affect society's well-being
 - Examples included diminished product variety, time costs of searching for substitutes, reduced convenience, etc.

Modeling Incremental Costs

- Find baseline TSC before policy
- Find TSC after policy is implemented
- Subtract baseline from new TSC
 - o TSC can be found as area under MSC
 - Recall $MSC = MAC_{MKT} + MCE$

MSC AND TSC OF ABATEMENT

MODELLING INCREMENTAL COSTS

Estimating Explicit Costs

- Two methods
 - o **Engineering Approach**
 - Estimates abatement spending based on *least-cost* available technology
 - Relies on experts in abatement methods
 - Drawbacks
 - difficult to use for *proposed* policy due to uncertainty
 - must be customized to suit each production setting or suffer from *averaging*
 - unable to capture firm heterogeneity as a generalized estimate

- likely understates true costs because it assumes all firms are cost-effective
- o **Survey Approach**
 - Derives estimated abatement expenditures from a sample of polluting sources via surveys
 - Drawbacks
 - assumes sources are sufficiently well-informed
 - polluters have an incentive to exaggerate costs to officials to increase the probability that the proposed regulation will be rejected
- Common to use a combination approach

Cost Classifications

- By economic sector
 - Shows cost distribution across public and private sectors
- By environmental media
 - Shows how costs vary across air, water, and solid waste abatement activities

Chapter 9 - Benefit-Cost Analysis in Environmental Decision Making

Benefit-Cost Analysis in Practice

- Two major steps follow the estimation of environmental benefits and costs
 1. Making time adjustments
 - Benefits and costs must be adjusted to account for how their values change over time
 2. Assessing relative values
 - Benefits and costs must be systematically compared
 - to determine feasibility
 - to choose among feasible options based on a decision rule

Time Adjustments

- Purpose of these adjustments
 - Benefits and costs do not accrue to society at the same time

- Benefits and costs often accrue in the future
- Two types of adjustments
 - Present value determination
 - accounts for the opportunity cost of money
 - Inflation correction
 - accounts for changes in the general price level

Present Value Determination

- General formula $PV = FV(1/[1 + r]^t)$ where:
 - $(1/[1 + r]^t)$ is the **discount factor**
 - t is number of time periods
 - r, the discount rate, is the only variable
 - called the **social discount rate** in public policy
 - r should reflect the **social opportunity cost of funds**
- PV determination is the means by which future environmental benefits and costs are adjusted

Inflation Correction

- Adjusting for movements in the general price level
 - Convert a real variable today to its future nominal value to account for expected inflation
 - $\text{Nominal value}_{\text{period } x+t} = \text{Real value}_{\text{period } x} \times (1 + p)^t$,
 - where p is the expected inflation rate
 - Converting a nominal value to its real value
 - $\text{Real value}_{\text{period } x} = \text{Nominal value}_{\text{period } x+t} / (1 + p)^t$
 - Known as **deflating**

Deriving Time-Adjusted Benefits and Costs

- Present value of benefits (PVB) is the time-adjusted magnitude of incremental benefits associated with an environmental policy change
 - PVB in real dollars is $PVB = S(b_t/[1+r_s]^t)$
 - where b_t represents real benefits

- Present value of costs (PVC) is the time adjusted magnitude of incremental costs associated with an environmental policy change
 - PVB in real dollars is $PVC = S(c_t/[1+r_s]^t)$
 - where c_t represents real costs

Benefit-Cost Analysis in Policy

Step One - Determining Feasibility

- Use the benefit-cost ratio
 - If $PVB/PVC > 1$ option is feasible

OR

- Use the present value of net benefits (PVNB), which equals $(PVB - PVC)$
 - If $PVNB > 0$ option is feasible

Step Two - Select Among Feasible Options

- Decision rule: To achieve allocative efficiency
 - Maximize PVNB = $S([b_t - c_t]/[1+r_s]^t)$ for all t periods, among all feasible alternatives
- Decision rule: To achieve cost-effectiveness:
 - Minimize PVC = $S(c_t/[1+r_s]^t)$ for all t periods, among all feasible alternatives that achieve a predetermined benefit level

Reservations About the Use of Benefit-Cost Analysis

- Measurement Problems
 - Estimation is particularly problematic due to intangibles
 - Implicit costs
- Equity Issues
 - Distribution of benefits and costs may be skewed

Federal Government Support

- [President Reagan's Executive Order 12291](#)
 - Explicitly called for maximizing net benefits (allocative efficiency) and choosing the least-cost alternative (cost-effectiveness)
 - Detail of potential benefits and costs to be given in a Regulatory Impact Analysis (RIA)

- Applicable to any “major rule,” i.e., a regulation expected to have an annual impact of at least \$100 million
- [President Clinton's Executive Order 12866](#)
 - Explicitly refers to adopting/proposing regulations for which benefits justify costs (allocative efficiency) and designing regulations in most cost-effective manner
 - Applicable to any “significant regulatory actions,” including those expected to have an annual impact of at least \$100 million
 - Detail to be given in an Economic Analysis (EA)
- [President Bush's Executive Order 13258](#)
 - Makes minor amendments to Clinton's Executive Order 12866
 - Extends the use of economic criteria in policy design and evaluation through an Economic Analysis
- [Obama's Executive Order 13563](#)
 - Reaffirmed and enhanced President Clinton's Executive Order 12866
 - Requires the following:
 - that a regulation can be proposed or adopted only if the benefits justify the costs.
 - that, if choosing among alternative regulatory initiatives, the one that maximizes net benefits should be chosen

Regulatory Impact Analysis (RIA) - Lead in Gasoline

- Estimated incremental benefits included health effects and nonhealth effects, such as increased fuel economy
- Estimated incremental costs were estimated using an engineering cost model of the refinery industry
- The resulting PVNB over the 1985 - 1992 period (excluding blood pressure effects) was estimated to be \$5.9 billion (\$1983) and supported the proposed new lead standard

UK Impact Assessment (IA) - Climate Change Act 2008

- The IA presented cost and benefit estimates for the proposal from the present to 2050
 - o Estimated benefits range from:
 - £457 billion to £1020 billion or \$739 billion to \$1,649 billion

- o Estimated costs range from:
 - £324 billion to £404 billion or \$524 billion to \$653 billion
- Estimated Net Benefits range from £53 billion to £696 billion (or \$86 billion to \$1,125 billion)

Chapter 10 - Defining Air Quality: The Standard-Setting Process

- Air quality in the U.S. and other nations is defined through standards that set limits on **anthropogenic pollutants**
 - Anthropogenic pollutants are contaminants associated with human activity
 - Natural pollutants are those that come about through nonartificial processes in nature

Overview of U.S. Air Quality Legislation

- Early evolution
 - There were no *national* air quality laws until the Air Pollution Control Act of 1955
 - There was no truly comprehensive legislation until Clean Air Act of 1963
- Current U.S. Policy
 - **1990 Clean Air Act (CAA) Amendments** use some market-based approaches, but continues to be command-and-control oriented
 - Cross-State Air Pollution Rule (CSAPR) was finalized by the EPA in July 2011
 - Replaces the Clean Air Interstate Rule (CAIR)
 - Calls for reductions in SO₂ and NO_x emissions transported across state borders, targeting power plants in eastern half of U.S.

Identifying Major Air Pollutants

- **Criteria pollutants** are substances known to be hazardous to health and welfare, characterized as harmful by criteria documents
- **Hazardous air pollutants** are noncriteria pollutants that may cause or contribute to irreversible illness or increased mortality
- **Greenhouse gas (GHG) pollutants** are those collectively responsible for the absorption process that naturally warms the earth

6 Criteria Air Pollutants

■

- *particulate matter (PM-10 and PM-2.5)*
- *sulfur dioxide (SO₂)*
- *carbon monoxide (CO)*
- *nitrogen dioxide (NO₂)*
- *tropospheric ozone (O₃)*
- *lead (Pb)*

Hazardous Air Pollutants

- 189 are identified in 1990 CAA Amendments
- Key distinctions from criteria pollutants
 - o They pose much greater risk
 - o They affect smaller segment of society

GHG Air Pollutants

- A U.S. Supreme Court decision found that greenhouse gases (GHGs) are pollutants covered by the Clean Air Act and that EPA is authorized to regulate them
- These GHGs include carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride

Setting Standards to Define Air Quality

- EPA sets national standards for the major air pollutants to be met by potentially controllable sources
 - o **Stationary sources** are fixed-site producers of pollution, such as a building or manufacturing plant
 - o **Mobile sources** are any nonstationary polluting sources, including all transport vehicles

Standards for Criteria Air Pollutants

- **National Ambient Air Quality Standards (NAAQS)** set maximum allowable concentrations of criteria air pollutants
 - o Primary NAAQS are set to protect public health from air pollution, with some margin of safety
 - o Secondary NAAQS are set to protect public welfare from any adverse, nonhealth effects of air pollution

Recent NAAQS Proposals

- Revision to the primary standard for SO₂

- o To enhance protection from short-term SO₂ exposure by replacing the 24-hour and annual standards with a one-hour standard
- Proposal to strengthen primary and secondary standards for O₃
 - o To help combat urban smog
 - o In 2011, President Obama requested that this be withdrawn because of slow economic growth

Standards for Hazardous Air Pollutants

- **National Emission Standards for Hazardous Air Pollutants (NESHAP)** are set to protect public health and the environment and are applicable to every major source of any identified hazardous air pollutant
 - o Maximum Achievable Control Technology (MACT) is the technology that achieves the reduction to be accomplished by the NESHAP

Standards for GHG Pollutants

- No ambient standards have been set, and none have been proposed
- Nonetheless, the EPA is determining *how* to lower GHG emissions now that the Supreme Court ruled that it has the authority to do so
 - o New emissions standards for mobile sources
 - o Permitting and reporting requirements for stationary sources and emissions standards for major GHG stationary sources

Recent NESHAP Proposals

- To reduce mercury and other toxics from industrial, commercial, and institutional boilers and incinerators
- To reduce heavy metals and acid gases released from coal-fired and oil-fired power plants
- Estimates for both suggest positive net benefits

Infrastructure To Implement the Standards: Two Key Elements

- **State Implementation Plan (SIP)**
 - An EPA-approved procedure outlining how a state intends to implement, monitor, and enforce the NAAQS and the NESHAP
- **Air Quality Control Region (AQCR)**
 - A federally-designated geographic area within which common air pollution problems are shared by several communities

Reclassification of AQCRs

- In 1974, following a suit filed by the Sierra Club, AQCRs were reassessed to identify 3 types of regions:
 - Regions that met or exceeded the standards as **Prevention of Significant Deterioration (PSD) areas**
 - Regions not in compliance with the standards as [nonattainment areas](#)
 - Regions with insufficient data
- In 1990, the new CAA Amendments reclassified all nonattainment areas into new categories that identified the severity of the pollution

Monitoring Air Quality Across Regions

- Estimating pollutant emissions levels
 - Best available engineering methods are used to derive annual emissions estimates for over 450 source categories
- Measuring pollutant concentrations
 - Pollutant concentration levels are measured at air-monitoring station sites located throughout the country
 - Most of these sites are in urban regions
 - Reported to the EPA via an air-monitoring network

Analysis of U.S. Air Quality Policy - Evaluation Criteria

- Equity criterion
 - [Environmental justice](#)
 - In 1993, environmental justice became one of the EPA's seven guiding principles
- Economic criterion
 - Allocative efficiency
 - Arises where marginal social costs (MSC) and marginal social benefits (MSB) are equal

Portney's Benefit-Cost Analysis of 1990 Policy

- Offers a point estimate for MSB of \$14 billion and a point estimate for MSC of \$32 billion annually

- Since MSC far outweighs MSB, it might be that Titles II through V of the 1990 Amendments *overregulate* society

Graphing Portney's Findings

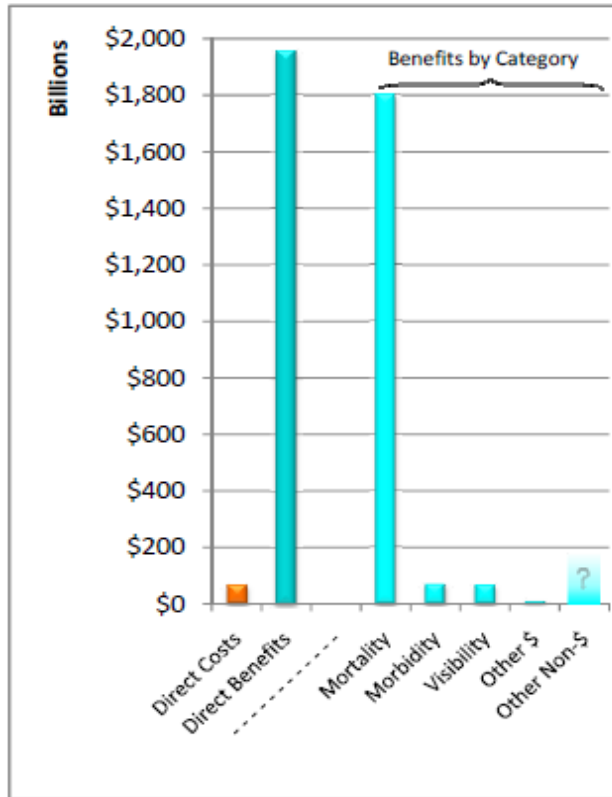
EPA's

*Benefit-Cost Analysis of 1990 Policy
(first prospective study)*

- In its first prospective analysis of the 1990 CAAA, the EPA estimated the following:
 - Present value of net benefits associated with Titles I through V of the 1990 CAAA for the 1990 to 2010 period is \$510 billion (\$1990)
 - Present value of net benefits for Title VI, protecting the ozone layer, is \$500 billion (\$1990) for 1990 to 2165
- EPA's quantitative results, though recognized as based on sound methods and data, are considered controversial on a number of fronts
 - Discussed in Freeman (2002) and Krupnick and Morgenstern (2002)

EPA's Benefit-Cost Analysis of 1990 Policy (second prospective study)

- In 2011, the EPA completed its second prospective analysis of the 1990 CAAA for the 1990 to 2020 period
- Estimates for 2020 are:
 - \$70.3 billion (\$2010) in costs
 - \$2,110.3 billion (\$2010) in benefits
 - \$2040 billion (\$2010) in net benefits
- Not comparable to the first study because of the use of different data and methods



Analysis of NAAQS

Two Potential Sources of Inefficiency

- No cost considerations in standard-setting
- Uniformity of the standards

Absence of Cost Considerations

- NAAQS are solely benefit-based
- Economic feasibility not explicitly considered
- Primary standards include “margin of safety”

Uniformity of NAAQS

- NAAQS are nationally based, ignoring regional cost or benefit differences
 - e.g. different pollution levels, technology access, demographics, etc.
- Exception is that distinctions are allowed for PSD areas
 - PSD areas face higher standards than NAAQS
 - Are higher standards for PSDs efficient?
 - Only if $MSC_{PSD} = MSB_{PSD}$ at a higher A level
 - Let's examine possible scenarios that support such an outcome

SCENARIOS ACHIEVING EFFICIENCY

Chapter 11 - Improving Air Quality: Controlling Mobile Sources

Measuring Urban Air Quality

- EPA monitors the air in relatively large metropolitan statistical areas (MSAs) and reports part of its findings using the [Air Quality Index \(AQI\)](#)
- AQI is reported as the highest of five pollutant-specific index values (ranging between 0 and 500) for that day and signifies the worst daily air quality in an urban area over a given time period
 - The pollutants monitored are five of the criteria pollutants, PM-10, SO₂, CO, O₃, and NO₂
 - An AQI of 100 is considered to correspond to the standard set by CAA

Photochemical Smog in Urban Areas

- Formed from pollutants that chemically react in sunlight to form new substances
- Principal component is tropospheric (ground-level) ozone (O₃)
 - Ozone is formed from a chemical reaction of NO_x and VOCs (smog precursors) and sunlight
 - Released by stationary and mobile sources
 - Highest emitters of smog precursors among transportation sources are gas-powered cars
 - See EPA's [Green Vehicle Guide](#) for information on new cars by model

Controlling Mobile Sources - 1990 Clean Air Act Amendments

- 1990 Clean Air Act Amendments strengthened U.S. controls on motor vehicle emissions and fuels through [Title II](#)
- Includes tougher emissions requirements, fuel quality controls, and incentives to encourage development of cleaner-running vehicles and cleaner alternative fuels

Emissions Reductions: Tier I

- Phased in between 1994 and 1998

- Panels (a) and (b) are not likely. Why?
 - MSB_{NON} likely higher than MSB_{PSD}
 - MSC_{NON} likely higher than MSC_{PSD}
- Panel (c) is possible only under a series of conditions
- Suggests that higher standards in PSD areas *may* be justifiable on efficiency grounds but only under certain economic conditions.

- Aimed at reducing emissions of non-methane hydrocarbons (NMHC), carbon monoxide (CO), nitrogen oxides (NO_x), and particulate matter (PM)
- Passenger cars and light trucks subject to tighter regulation than heavier SUVs, minivans, pickup trucks
 - Stricter controls for initial 5 years or 50,000 miles of use; less stringent controls for remainder of vehicle's useful life redefined as 10 years or 100,000 miles

Emissions Reductions: Tier II

- Phased in between 2004 and 2008
- Tougher requirements given for each successive model year
- Unique to this tier of controls is:
 - o an interrelated system of controls on vehicles and fuels
 - o no distinction for vehicle size

Fuel Quality Controls

- Prohibits leaded fuel after 1995
- Requires **reformulated gasoline** in certain ozone nonattainment areas
 - Fuels that emit less hydrocarbons, carbon monoxide, and toxics than conventional gasoline
- Requires **oxygenated fuel** in certain CO nonattainment areas
 - Formulations with enhanced oxygen content to allow for more complete combustion and hence a reduction in CO emissions

Clean Fuel Vehicles

- 1990 amendments set up clean fuel vehicles program
 - A clean fuel vehicle is certified to meet stringent emission standards for such pollutants as CO, NO_x, PM, formaldehyde
- In ozone and CO nonattainment areas, a proportion of new fleet vehicles had to be clean fuel vehicles and had to use clean alternative fuels
 - These are fuels such as methanol, ethanol blends (e.g., E10, E85), or power sources, such as electricity
- Market incentives include credits to fleet owners who surpass requirements in the law, tax credits for hybrids, fuel cell and alternative fuel vehicles, plug-in hybrids

Reducing GHGs: Light-Duty Vehicles

- In 2010, EPA and the National Highway Traffic Safety Administration (NHTSA) launched an initiative to:
 - Reduce GHG emissions from light-duty mobile sources
 - Improve fuel efficiency through [CAFE standards](#)
- Affects passenger cars and light-duty vehicles for model years 2012 to 2016
 - Must meet average emissions level of 250 grams of CO₂ for model year 2016

Reducing GHGs: Medium- and Heavy-Duty Vehicles

- In 2011, the EPA and the National Highway Traffic Safety Administration (NHTSA) launched a national initiative called the **HD National Program** to:
 - Reduce GHG emissions from mobile sources
- Affects three defined categories of medium- and heavy-duty vehicles for model years 2014 to 2018
 - Combined standards expected to reduce CO₂ emissions by 270 million metric tons and save 530 million barrels of oil over the life of the affected model year vehicles

Reducing GHGs: Next Steps

- EPA and NHTSA have proposed a second phase of standards for light-duty vehicles for 2017-to-2025 models
- The agencies are also considering a second phase under the HD National Program beginning with the 2018 model year

Analyzing Mobile Source Controls - Policy Characteristics to Analyze

- absence of benefit-cost analysis in setting emissions standards
- uniformity of auto emissions standards
- inherent bias against new vehicles
- implications of clean fuel alternatives
- market assessment of GHG emission controls

Absence of Benefit-Cost Analysis - An Inefficient Decision Rule

- New standards were technology forcing, i.e., set specifically to compel auto industry to find solutions
 - o Perversely gave manufacturers a strong case to seek adjustments and postponements for compliance

- New standards were benefit-based
 - Set solely to protect public health and welfare
 - Implies the standards were set to maximize TSB, where $MSB = 0$ versus to achieve efficiency, where $MSB = MSC$

BENEFIT-BASED EMISSION STANDARDS

Uniformity of Auto Emissions Standards

- With few exceptions, emission standards are applicable on every model produced with no regard to where the vehicle will be driven
 - This overregulates “clean” areas and underregulates “dirty” areas because MSB in more polluted regions should be higher than in cleaner regions, making the efficient abatement level higher in dirtier regions
 - This adds to costs with no offsetting benefits
- Studies suggest there would be considerable cost savings if a two-tiered standard replaced the uniform standard

TWO-TIERED STANDARD

Bias Against New Vehicles

- More stringent controls on new vehicles creates market distortion
 - Biases consumer decisions against new cars by influencing relative price and performance
 - Price Effect: regulations on new cars adds to costs which elevates relative price
 - Performance Effect: regulations adversely affect acceleration and gas mileage
- As $P_{NewCars}$, $D_{UsedCars}$ increases (substitutes), which perversely encourages use of higher-emitting cars

Implications of Clean Fuel Alternatives

- Advanced fuels are required only in the dirtier regions of the country
- Since this aligns *higher* MSC of developing and using new fuels with *higher* MSB of cleaning up in dirtier regions, it may approach an **efficient solution**

Tax Credits for Clean Fuel Vehicles

- Tax credits act like subsidies, shifting up the MPB by the amount of the credit
- If the credit equals the MEB at Q_E , an efficient equilibrium is achieved

TAX CREDITS ON PLUG-IN HYBRIDS

Benefit-Cost Analysis of GHG Emissions Program

- Light-duty Program
 - Estimated costs of the program are less than \$52 billion
 - Estimated benefits are \$240 billion
 - Monetized benefits include fuel savings, enhanced energy security, and PM-2.5 improvements
- HD National Program
 - Estimated costs are \$8 billion
 - Estimated benefits are more than \$57 billion

Market-Based Elements in GHG Emissions Programs

- Both programs use a system of averaging, banking, and trading (ABT) of emission credits
- Other available credits include --
 - Early credits for meeting reductions before the target model year
 - Advanced technology credits

Chapter 12 - Improving Air Quality: Controlling Stationary

What is Acidic Deposition(Acid Rain)?

Controlling Stationary Sources

- Stationary sources include electric power plants, chemical plants, steel mills, etc.
- Primary controls in the U.S. are technology-based standards with emissions trading programs added over time
- These controls vary with

- Occurs when sulfuric and nitric acids mix with other airborne particles and fall to earth as wet or dry deposits
- These acids arise from the chemical reaction of SO_2 and NO_x emissions with water vapors and oxidants in atmosphere
- SO_2 is the more significant contributor
 - Major sources are fossil-fueled electricity plants, refineries, and

- o Facility age (new versus existing)
- o Facility location (PSD versus nonattainment area)

Technology-based Standards - Dual-control Approach

- For new/modified stationary sources
 - o **EPA**-administered stringent limits, New Source Performance Standards (NSPS), are used based on access to new technology
- For existing stationary sources
 - o **State**-administered limits are used to give states control over industries affecting local economies
- Both limits are applied *uniformly* across firms within a given category

Setting the Control Technologies

- **PSD areas** (more stringent)
 - o New sources: limits based on best available control technology (BACT)
 - most stringent control technology
 - o Existing sources: limits based on best available retrofit technology (BART)
- **Nonattainment areas** (less stringent)
 - o New sources: limits based on lowest achievable emissions rate (LAER)
 - o Existing sources: limits based on reasonable available control technology (RACT)
 - least stringent control technology

Control Technologies - Summing it Up

- Emissions limits for PSD areas are more stringent than in nonattainment areas
- Limits for New Sources are more stringent than those for Existing Sources within both types of areas

Reducing GHG Emissions

- New GHG emissions standards for mobile sources triggered controls for stationary sources
 - o New and modified stationary sources of GHGs are now subject to New Source Review permitting requirements

- o Fossil fuel power plants and refineries to face New Source Performance Standards for GHG emissions

Emissions Trading

- For existing sources
 - o **Bubble policy**: plants can measure emissions of a single pollutant as an *average* of all emission points
 - o **Emissions banking**: a source can save emission reduction credits if it cuts emissions more than required by law and can deposit these through a banking program
- For new/modified sources
 - o **Netting** was devised for use in **PSD areas** by modified sources
 - o **Offset plans** were established for use in **nonattainment areas** by new or modified sources

Acid Rain Program (ARP) - SO₂ Emissions Allowance Trading

- [Title IV](#) of the 1990 CAAA established a two-phase acid rain initiative, establishing:
 - o a reduction plan for NO_x emissions
 - o a cap and trade allowance program for SO₂ emissions
- Phase I for the 1995–1999 period; phase II for the 2000–2009 period

Emissions Reduction for NO_x

- To be achieved through performance standards set by the EPA
- Objective was to reduce annual NO_x emissions to 2 million tons lower than what was forecasted for 2000
 - o This objective was met in 2000 and in every subsequent year to date.

Cap and Trade Program for SO₂

- National SO₂ emissions caps
 - o Permanent annual cap of 9.5 million tons for electric power plants starting in 2000; tightened to 8.95 million tons for 2010
- SO₂ Emissions Allowance Program
 - o EPA issues **tradeable emission allowances** for 1 ton of SO₂ each
 - o Total number issued sets the national limit

- Plants reducing emissions beyond limits can sell allowances to those exceeding limits
 - Low-cost abaters should do more abating
 - Cost-effectiveness can be achieved
- [Auctions](#) also held for direct sale of allowances
 - Administered by EPA (formerly by Chicago Board of Trade)

Clean Air Interstate Rule (CAIR) and SO₂

- Issued in 2005 by the EPA
- Comprised of 3 trading programs, including an annual SO₂ trading program in 2010
- CAIR was challenged
 - Would remain in force until replacement rule was issued
 - [Cross-State Air Pollution Rule \(CSAPR\)](#) has been finalized and will replace the CAIR

Ozone Control - NO_x Cap-and-Trade Programs

- Established under CAAA 1990, the Ozone Transport Commission (OTC) developed OTC NO_x Budget Program, a cap-and-trade plan
- In 1998, a new initiative, NO_x SIP call, required affected states to submit revised State Implementation Plans (SIPs) to achieve certain emission limits during ozone season, starting in 2003
 - EPA recommended using a cap-and-trade program and established **NO_x Budget Trading Program (NBP)** in 2003 as successor to original OTC program
 - 20 states plus District of Columbia participated

Clean Air Interstate Rule (CAIR) and NO_x

- Two of the three trading programs under the CAIR deal with NO_x
 - Both trading programs started in 2009
 - Both establish declining emissions caps
- CAIR was replaced by the Cross-State Air Pollution Rule (CSAPR)

State-Level Trading Programs

- [RECLAIM](#) is the Regional Clean Air Incentives Market Program developed in California

- Operates market for SO₂ and NOX
 - Uses RECLAIM trading credits (RTCs), each representing 1 pound of emissions
- Other states have also developed emissions trading programs
 - e.g., Colorado, Illinois, Massachusetts, Texas

Benefit-Cost Analysis of the ARP

- A 2005 study by Chestnut and Mills (2005), estimate the overall benefits and costs of the Acid Rain Program (ARP)
 - By 2010, the year by which the ARP is fully implemented, estimated annual benefits are \$122 billion (\$2000), and estimated annual costs are \$3 billion (\$2000)
 - Results suggest that the ARP is feasible from a benefit-cost perspective, generating nearly \$120 billion in net benefits annually

Higher Cost of CAC Methods

- Standards-based approach is cost-*ineffective*
 - Inflexibility adds to society's costs and gives low-cost abaters no incentive to clean up beyond level set by law
 - In most cases, cost savings can be achieved by shifting to more flexible policy instruments with no reduction in air quality benefits
- Most empirical studies show that the cost of using a command-and-control instrument *relative* to the least-cost method is greater than 1

Uniform Technology-Based Standards - NSPS Are Not Cost-Effective

- Uniformity disallows cost-effective solution
 - Each source within an industry must meet *same* standard
 - Cost-effectiveness requires equal MACs, not equal abatement levels
- Mandated abatement technology may not be the least-cost approach

New Source Bias - Dual Control Approach

- Existing sources are controlled by states, which have an incentive to set relatively lenient standards to avoid losing firms to other states
- In turn, firms have an incentive not to initiate new construction to avoid the more stringent and more costly NSPS

- Result is that the dual control approach perversely discourages construction of new and presumably cleaner-running new facilities

Cost-effectiveness of Emissions Trading Programs (SO₂ and NO_x)

- Low-cost abaters will reduce emissions and sell excess allowances (suppliers)
 - Will **sell** at any P **higher** than their MAC
- High-cost abaters will buy allowances rather than abate (demanders)
 - Will **buy** at any P **lower** than their MAC
- Trading should continue until MACs are equal, achieving a cost-effective solution

POLLUTER'S ABATEMENT DECISION - EXAMPLE: SO₂ ABATEMENT

Chapter 12 - Global Air Quality Policies for Ozone Depletion and Climate Change

- Ozone depletion refers to the thinning of the stratospheric ozone layer
 - Result is a loss of earth's protection from UV radiation
- Primary ozone depleters are chlorofluorocarbons (CFCs) and halons
 - These break down in UV light, releasing chlorine, which destroys stratospheric ozone molecules

Controlling Ozone Depletion – International and Domestic Policy

International Policy - Montreal Protocol and Amendments

- Montreal Protocol was signed in 1987 by 24 major countries
 - Called for 50% reduction of CFC consumption and production through 2000
- Amendments outlined a full phase out plan for CFCs, halons, and other depleters
 - HCFCs to be phased out by 2020; all other ozone-depleters were phased out of production on or before 2005
- Tradeable allowances were issued to Protocol participants
- An Interim Multilateral Fund was established in 1990 to help developing nations develop CFC replacement technologies
 - Fund became permanent in 1992

Domestic Policy on Ozone Depletion - Title VI of 1990 CAA

- Required EPA to publish a list of ozone depleters
 - Assign each an ozone depletion potential (ODP) value
 - Establish phaseout schedule for each
- Established a national mandatory recycling program to allow use of recycled chemicals beyond phaseout date
- Called for programs and research to find safe substitutes
- Legislated 2 market instruments to meet phaseout schedule
 - Escalating excise tax on production for sale
 - Marketable allowance system

Excise Tax on Ozone Depleters - Enacted by Congress in 1990

- Excise Tax per pound = $\text{base}_t * \text{ODP}$, where
 - base is the tax rate per pound
 - t is the year in the phaseout schedule
- The base as t (i.e., escalating)
 - In 1990, base tax rate = \$1.37/pound
 - In 1995, base tax rate = \$5.35/pound
 - In 2012, base tax rate = 13.00/pound
 - based on an annual increase of \$.45/pound starting in 1996
- Acts as a product charge
 - An excise tax set equal to the MEC at the efficient output level, Q_E , achieves an efficient resource allocation

MODELING EXCISE TAX

Allowance Market

- For CFCs
 - Tradeable allowances were issued to largest producers and consumers
 - Each allowed a one-time release based on its ODP
 - The number of allowances were gradually reduced to 0 to meet phaseout deadlines

- For HCFCs
 - o EPA is establishing an analogous program

Economic Analysis of Ozone Depletion Policy

Regulatory Impact Analysis (RIA) for the Phaseout of Ozone Depleters

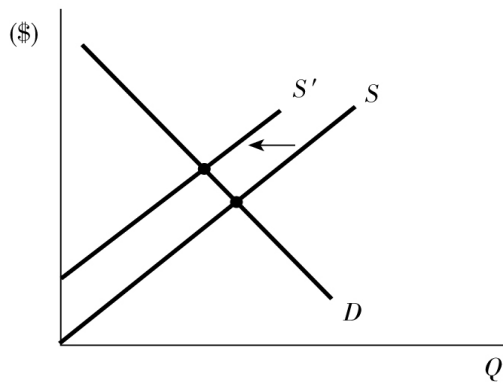
- Benefit estimate= \$6.5 trillion through 2075
 - o includes health and nonhealth effects
- Cost estimate = \$27 billion through 2075
 - o impact on air conditioning and refrigeration
- Result: U.S. regulations to control ozone depleters were announced in August 1988, less than one year after the signing of the Montreal Protocol

Assessing Cost-Effectiveness

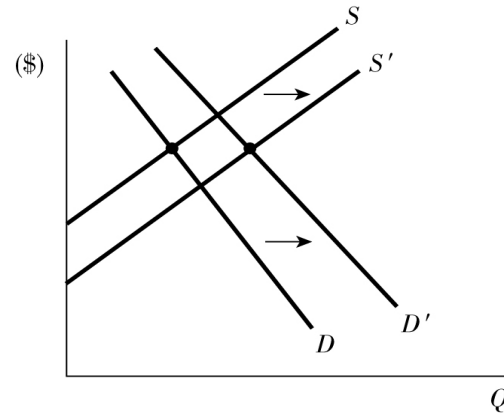
- EPA-commissioned a study conducted by Rand Corporation, which investigated three alternative control approaches
- Costs for each approach were as follows
 - o Technology-based command-and-control approach: \$185.3 million
 - o Fixed emission charges: \$107.8 million
 - o Tradeable emissions permit system: \$94.7 million
- Supports the expectation that allowance trading would approach a cost-effective solution

Price Adjustments

- In the CFC market
 - o The phaseout plan and excise tax caused supply (S) of CFCs to shift leftward, raising price, so Qd^-
 - o As price of CFCs rose, demand (D) for CFC substitutes increased
- In the CFC-substitute market
 - o Technology-driven cost declines in production of CFC substitutes would shift S of substitutes rightward



Market for CFCs



Market for CFC Substitutes

Incentives and Disincentives - Market for CFC substitutes

- Incentive
 - Profit advantage of producing substitutes when prices were high may encourage production
- Disincentive
 - Market power of the relatively small number of firms holding allowances may have deterred development of substitutes
 - Market power & high prices on CFCs & abnormal profits & less incentive to find substitutes
 - Corrected in part by the excise tax, which redistributed some of these profits

Phase Down of HFCs - Substitutes for Ozone-Depleters

- HFCs do not damage the ozone layer, but they are GHGs, contributing to climate change
 - In 2009, the federated states of Micronesia and Mauritius proposed phasing down HFCs as an amendment to the Montreal Protocol
 - In 2011, Canada, Mexico, and the U.S. submitted a similar proposal
- If proposals are accepted, the phase down should motivate development of substitutes

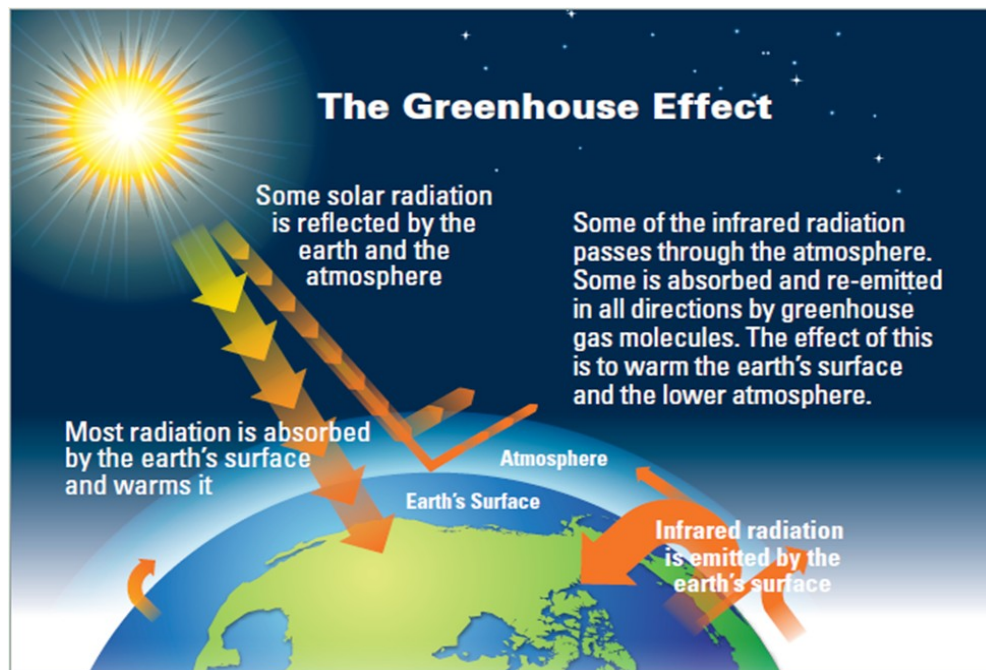
Climate Change

- **Climate change** refers to a major alteration in a climate measure such as temperature, wind, and precipitation that is prolonged, i.e., lasting decades or longer

- A source of controversy is the predicted climate response to the increasing production of what are termed **greenhouse gases (GHGs)**

What is **Global Warming**?

- Sunlight hits earth's surface, radiates back into atmosphere, where its absorption by GHGs heats atmosphere and warms earth's surface
 - Sometimes called the "greenhouse effect"
- Warming process is natural; becomes problematic if natural GHG levels are disrupted
- Among the primary GHGs is carbon dioxide (CO₂)
 - Accumulating CO₂ is linked to fossil fuel combustion and deforestation
 - Capacity of each GHG to trap heat relative to CO₂ is measured by a global warming potential (GWP)



Policy Response to Climate Change - International

Separating Myth from Facts

- Most agree that GHGs (CO₂) are rising
- Scientists agree that rising GHGs will affect climate
 - Uncertainty is about when this may happen and the extent of effect

- See recent scientific reports:
 - Report by [National Assessment Synthesis Team](#)
 - Fourth Assessment Report by [Intergovernmental Panel on Climate Change \(IPCC\)](#)
 - Fifth Assessment Report is in progress

U.N. Framework Convention on Climate Change (UNFCCC)

- An agreement reached at the 1992 Rio Summit that dealt with global warming and other air quality issues
 - Called for nations to implement national strategies to limit GHG emissions with the objective of reducing emissions to 1990 levels by 2000
 - Avoided uniform emissions targets to accommodate differences in political and economic conditions
 - Encouraged signatories to recognize climate change in devising economic, social, and environmental policies.
 - Provided for assistance to developing nations by industrialized countries in obtaining data and in limiting emissions

Kyoto Protocol to the UNFCCC

- In July 2001, 178 nations reached an agreement that required 38 industrialized countries to cut GHG emissions to 5.2% below 1990 levels by 2012
 - Developing countries had no emissions requirements
 - Because of their exclusion, U.S. did not ratify the agreement
- During commitment phase from 2008 to 2012, emissions targets to be achieved using **flexible mechanisms, including:**
 - GHG allowance trading system for developed nations
 - Credits for carbon-absorbing forestry practices and emissions-reducing projects in other nations
- Protocol entered into force in 2005 after being ratified by developed nations representing at least 55% of carbon emissions

United Nations Climate Change Conferences COP15, COP16, and COP17

- Copenhagen was venue of COP15 in 2009

- o Copenhagen Accord included nonbinding pledges to reduce GHG emissions
- Mexico hosted COP16 in 2010
 - o Cancun Agreements included
 - goal to keep the average global temperature rise at less than 2 degrees Celsius
 - decision to establish Green Climate Fund to help developing nations
- At COP17 in Durban, South Africa
 - o Durban Platform included agreements to
 - extend the Kyoto Protocol
 - establish a successor agreement by 2015
 - implement the Green Climate Fund

European Union (EU) Response

- EU launched its own GHG trading program in 2005 called [European Union GHG Emissions Trading Scheme \(EU ETS\)](#)
 - o 2 trading phases, with the second aligned with the first commitment phase of Kyoto Protocol
 - o Allowances are exchanged through electronic registries
- EU proposed a carbon tax in 2011 at a minimum rate of EUR 20 per metric ton of CO₂
 - o Some EU countries already have a carbon tax, including Belgium, Denmark, Italy, Norway, Sweden

Policy Response to Climate Change - Domestic

President Bush's Initiative

- Called for a cabinet-level review of U.S. climate change policy and formed climate change working group
- Presented results as *Global Climate Change Policy Book* released in February 2002
 - o Goal was to reduce GHG intensity by 18% by 2012
 - Equivalent to the average across Kyoto participants

President Obama's Position

- Pledged the U.S. to a reduction in GHG emissions of 17 percent from 2005 levels by 2020 as part of Copenhagen Accord, but the pledge is not binding
- This pledge was included in several bills introduced in Congress, some with a cap-and-trade program, but none became law
- New rulings on mobile sources and stationary sources have been finalized or proposed

Controlling GHGs in the U.S.

- In 2009, the EPA announced 2 proposed findings:
 - o Endangerment Finding:
 - that six GHGs pose a threat to public health and welfare
 - o Cause or Contribute Finding:
 - that vehicle emissions add to GHGs in the atmosphere and contribute to climate change
 - o Result of the two findings:
 - New GHG emissions standards and CAFÉ standards on light-duty vehicles for model years 2012 to 2016, effective in January 2011 with proposed standards for 2017 and beyond
 - New GHG emissions standards for medium- and heavy-duty vehicles for 2014-to-2018 model years with a second phase under consideration for 2018 and beyond
 - Proposed permitting requirements and emissions standards for stationary sources

U.S. Regional Responses - Two Examples

- Regional Greenhouse Gas Initiative (RGGI)
 - o 10 states participate in mandatory cap-and-trade GHG program for power plants
 - Cap lowered over time until 10% below initial level by 2018
 - o Tradeable allowances sold at auctions, using proceeds for low-carbon, clean energy technologies
- Western Climate Initiative (WCI)

- o 7 states and 4 Canadian provinces collaborate to achieve 15% reduction in GHG releases below 2005 levels by 2020
 - Cap-and-trade schedule to be launched in 2012

Economic Analysis of Climate Change Policy

Benefits of Controlling GHGs - Important to Policy Development

- OECD estimates (\$1990) of annual damage
 - o \$61.6 B (based on 2.5° C rise)
 - o \$338.6 B (based on 10° C rise over 250-400 years)
- Beckerman (1990) cites an EPA estimate of the net effect at between -\$10B and +\$10B
- Mendelsohn and Neumann (1999) estimate the net benefit to the U.S. would be 0.1 percent of GDP
- Nordhaus and Boyer (2000) estimate the comparable value at approximately -0.5 percent of GDP
- Stern (2007) estimates that with no policy, costs could be 5% to 20% of global GDP per year but costs of responding by controlling GHGs can be limited to 1% per year

Market Failure Analysis - Negative Externality

- Production of electricity using fossil fuels is associated with release of CO₂ emissions -- a **negative externality**
- Utilities using fossil fuels do not consider the external costs of CO₂ emissions and allocate too many resources to production, and too few are allocated to alternative fuels
- Solution depends on government intervention through policy

Market-Based Policy Option - Pollution Charges

- o A **pollution charge** is a fee that varies with the amount of pollutants released
- o Three types commonly proposed for climate change issues are:
 - Gasoline tax – a per unit tax levied on each gallon of gasoline consumed
 - Btu tax – a per unit charge based on the energy content of fuel, measured in British thermal units (Btu)
 - Carbon tax – a per unit charge based on the carbon content of fuel

Analyzing Pollution Charges

- Drawbacks of a gasoline tax
 - Targets only polluting sources using gasoline, which are relatively minor CO₂ emitters
 - Imposes a disproportionate burden on some, such as rural communities lacking good public transportation and industries like interstate trucking
- So the broader based carbon tax or Btu tax is often proposed as a better alternative
 - Carbon tax becoming more prevalent worldwide
- Btu tax and carbon tax each use a slightly different tax base, but both encourage fuel switching and conservation by raising fuel prices
- Carbon tax is more specific, targeting only carbon-based fuels
 - It changes *relative* fuel prices and could elevate the price by the *MEC* of the environmental damage, internalizing the negative externality

Market-Based Policy Option - Tradeable Permit Systems

- Primary means by which developed nations are to achieve their respective emissions targets under the Kyoto Protocol
- European Union (EU) established its own trading program: EU Emissions Trading Scheme (EU ETS)
- Trading can lead to cost-effectiveness
 - Nations best able to reduce emissions do so and sell permits; those that could not would buy permits

Chapter 18 – Managing Municipal solid Waste

Problem of MSW

- MSW is nonhazardous waste posing no *direct* threat to humans or ecology
- Still there are risks
 - Excess generation
 - Improper management, which can lead to...
 - bacterial contamination: unsanitary conditions

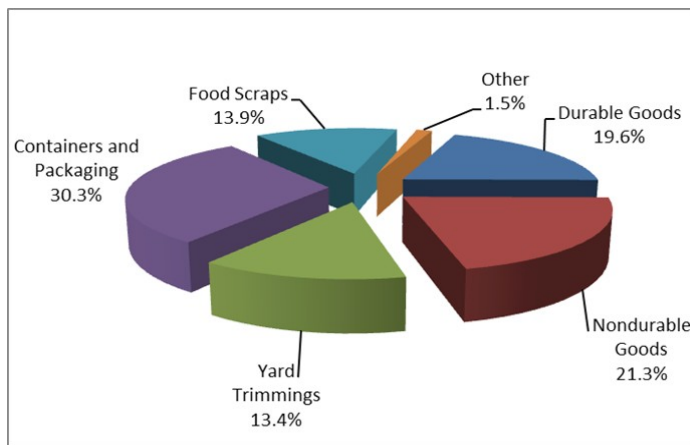
- toxic contamination: hazardous wastes mixed in
- air pollution: incineration or decomposition gases

MSW Trends

- o MSW generation is growing, both total and per capita
- o Dependence on landfills continues
 - o In 2010, over 54% of MSW was landfilled in the U.S.
- o Composition of MSW
 - o largest proportion by product: containers & packaging
 - o largest proportion by materials: paper & paperboard
- o Major industrialized nations are largest generators
- o Recycling rates vary across nations
 - o In 2009, Germany had the highest recycling rate in the EU at 48%; Sweden and Belgium are next at 36% each
 - o U.S. overall recycling rate in 2009 was 33.8%

U.S Data

| | 1980 | 1990 | 2000 | 2010 |
|--|---------|---------|---------|---------|
| MSW (millions tons) | 151.6 | 208.3 | 242.5 | 249.9 |
| Population (thousands) | 227,726 | 250,181 | 282,418 | 310,109 |
| Per capita MSW (pounds/day) | 3.65 | 4.56 | 4.70 | 4.42 |



Recycling Plastics

- o Plastic wastes have grown over time
 - o 390,000 tons in 1960; 31 million tons in 2010
 - o Largest proportion of plastic wastes is containers and packaging
- o Recovery rate is 7.6 percent (2010), which is low compared to other materials
- o Recycling process for plastics is complex
 - Must be sorted by resin content, and some plastic wastes are not readily identified

INTERNATIONAL RANKING – BY PER CAPITA GENERATION

| Country | kilograms per capita |
|-----------------------|-----------------------------|
| United States | 745 |
| Netherlands | 623 |
| Germany | 581 |
| Spain | 575 |
| United Kingdom | 546 |
| Italy | 545 |
| France | 543 |
| Sweden | 515 |
| Norway | 490 |

Policy under RCRA (Subtitle D)

- o **Federal responsibilities**
 - o To give financial and technical assistance to states, encourage resource conservation, set minimum criteria for land disposal, incineration facilities, etc.
- o **States' responsibilities**
 - o To develop waste management plans
 - Many follow EPA's **integrated waste management system**, which promotes using a combination of programs aimed at source reduction, recycling, combustion, and land disposal – in that order

- o To use regulatory powers to comply with RCRA
 - e.g., recycling laws, grant programs

[EPA'S INTEGRATED WASTE MANAGEMENT SYSTEM](#)

MSW Services Markets

Modeling the MSW Market

- o Supply (S), or MPC, represents the production decisions of firms providing MSW services
- o Demand (D), or MPB, represents the purchasing decisions of MSW generators

Two Sources of Resource Misallocation

- o **Flat fee pricing of MSW services does not reflect rising MPC associated with increases in production levels.**
- o Production of MSW services is associated with **negative externalities**, which means that private market equilibria, where $MPB = MPC$ do not yield an efficient solution

Flat Fee Pricing System

- o Communities typically charge the same fixed fee regardless of amount of MSW generated
 - o Fee typically hidden in property taxes
- o Demanders pay a zero Marginal Price **as if** MPC were 0
 - o Ignores positive and rising MPC of MSW services
- o Result:
 - o No incentive to reduce wastes
 - o Too many resources allocated to MSW services

Negative Externality

- o Production externality causes resource misallocation even if the fee reflects rising MPC
- o External costs (MEC) are due to air pollution from incineration, groundwater contamination, etc.

- o Result:
 - o Overallocation of resources to MSW services

Market-Based Solutions

Back-end or Waste-end Charge

- o Imposed on **waste** at time of **disposal**
 - o Efficiency is achieved if the fee, P_E , equals to MSC at Q_E
- o Known as unit pricing, or pay-as-you-throw (PAYT), programs
 - o Can be implemented as flat rate or variable rate pricing
- o Real-world usage
 - o Used in over 7,000 communities in the U.S.
 - Some use **bag-and-tag systems**
 - o Empirical evidence
 - \$0.50 per container led to reduction of 3,650 tons/year for a community of 100,000 people (Jenkins 1993)

UNIT PRICING – IMPLEMENTED AS A WASTE-END CHARGE

Front-end or Retail Disposal Charge

- o Imposed on the **product** at point of **sale**
- o Should encourage prevention through source reduction
- o Used domestically and internationally
 - o e.g., U.S. states use for tires, fertilizers; Belgium, Denmark, Portugal use for batteries; Norway, Sweden use for pesticides
- o Aimed at a **consumption externality**
- o Efficiency is achieved if front-end charge equals $-(MEB)$ at Q_E
- o Effective price of product (P_R) includes fee

RETAIL DISPOSAL CHARGE - A FRONT-END CHARGE

Deposit/Refund System (review from Chapter 5)

- o Up-front fee imposed on a product at point of sale (like retail disposal charge)
 - o Fee equals MEC of improper disposal, or the negative MEB of consumption
- o Fee is returned if consumer takes proper action to avoid environmental damages
- o Real world examples
 - For beverage containers: Australia, Canada, Denmark, Finland, Iceland, Italy, the Netherlands, Norway, Sweden, Turkey, United States
 - For auto bodies: Denmark, Finland, Norway, Sweden