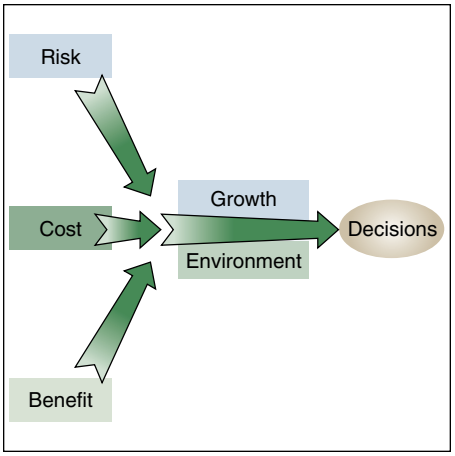
CHAPTER 3

Risk and Cost: Elements of Decision Making



Objectives

After reading this chapter, you should be able to:

- Describe why the analysis of risk has become an important tool in environmental decision making.
- Understand the difference between risk assessment and risk management.
- Describe the issues involved in risk management.
- Understand the difference between true and perceived risks.
- Define what an economic good or service is.
- Understand the relationship between the available supply of a commodity or service and its price.
- Understand how and why cost-benefit analysis is used.
- Understand the concept of sustainable development.
- Understand environmental external costs and the economics of pollution prevention.
- Understand the market approach to curbing pollution.

Chapter Outline

Measuring Risk

Two factors are primary in many decisions in life: risk and cost. We commonly ask such questions as "How likely is it that someone will be hurt?" and "What is the cost of this course of action?" Environmental decision making is no different. If a new air-pollution regulation is contemplated, industry will be sure to point out that it will cost a considerable amount of money to put these controls in place and will reduce profitability. Citizens will point out that their tax money will have to support another governmental bureaucracy. On the other side, advocates will point out the reduced risk of illnesses and the reduced cost of health care for people who live in areas of heavy air pollution.

Risk analysis has become an important decision-making tool at all levels of society. In the area of environmental concerns, assessing and managing risks help us determine what environmental policies are appropriate. The analysis of risk generally involves a probability statement. **Probability** is a mathematical statement about how likely it is that something will happen. Probability is often stated in terms like "The probability of developing a particular illness is 1 in 10,000," or "The likelihood of winning the lottery is 1 in 5,000,000." It is important to make a distinction between *probability* and *possibility.* When we say something is *possible,* we are just saying that it could occur. It is a very inexact term. *Probability* defines how likely *possible* events are.

Another important consideration is the consequences of an event. If a disease is likely to make 50 percent of the population ill (the probability of becoming ill is 50 percent) but no one dies, that is very different from analyzing the safety of a dam, which if it failed would cause the deaths of thousands of people downstream. We would certainly not accept a 50 percent probability that the dam would fail. Even a 1 percent probability in that case would be unacceptable. The assessment and management of risk involve an understanding of probability and the consequences of decisions. (See figure 3.1.)

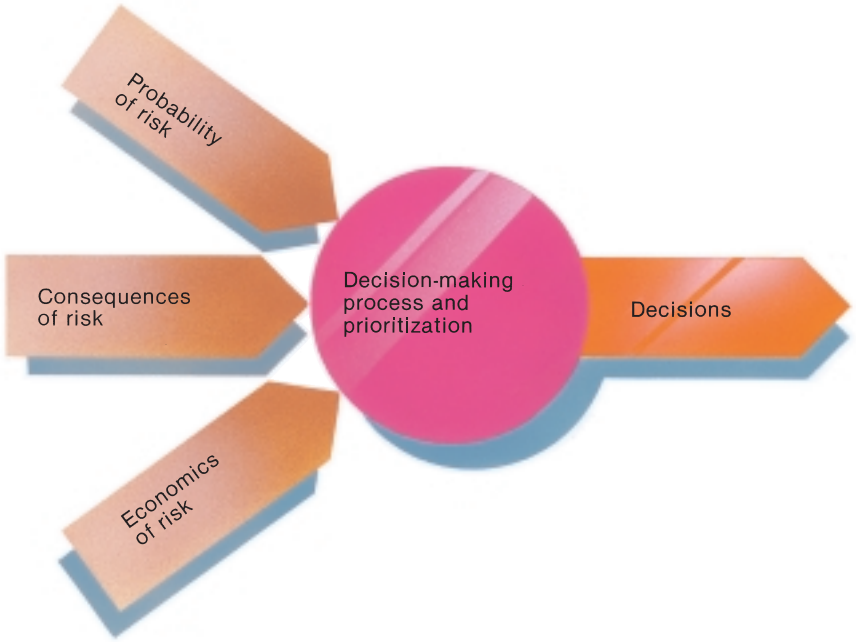


figure 3.1 **Decision-Making Process** The assessment, cost, and consequences of risks are all important to the decision-making process.

Risk assessment involves analyzing a risk to determine the probability of an adverse effect. Risk management is a much broader task that includes assessment and the consequences of risks in the decision-making process. We will look at both these tasks in the next two sections.

Risk Assessment

Environmental **risk assessment** is the use of facts and assumptions to estimate the probability of harm to human health or the environment that may result from exposures to pollutants, toxic agents, or management decisions. What risk assessment provides for environmental decision makers is an orderly, clearly stated, and consistent way to deal with scientific issues when evaluating whether a hazard exists and what the magnitude of the hazard may be.

Calculating the hazardous risk to humans of a particular activity, chemical, or technology is difficult. If a technology is well known, scientists use probabilities based on past experience to estimate risks. For example, the risk of developing black lung disease from coal dust in mines is well established. To predict the risks associated with new technology, much less accurate statistical probabilities, based on models rather than real-life experiences, must be used.

Risks associated with new chemicals are difficult to quantify. While animal tests are widely accepted in predicting whether or not a chemical will cause cancer in humans, their use in predicting how many cancers will be caused in a group of exposed people is still very controversial. Most risk assessments are *estimates* of the probability that a person will develop cancer or other negative effects. (See figure 3.2.)

Such estimates typically are based on broad assumptions to ensure that a lack of complete knowledge does not result in an underestimation of the risk. For example, people may be more or less sensitive to the effects of certain chemicals than the laboratory animals studied. Also, people vary in their sensitivity to cancer-causing compounds. Thus, what may present no risk to one person may be a high risk to others. Persons with breathing difficulties are more likely to be adversely affected by high levels of air pollutants than are healthy individuals. In addition, the estimate of human risk is based on extrapolation from animal tests in which high, chronic

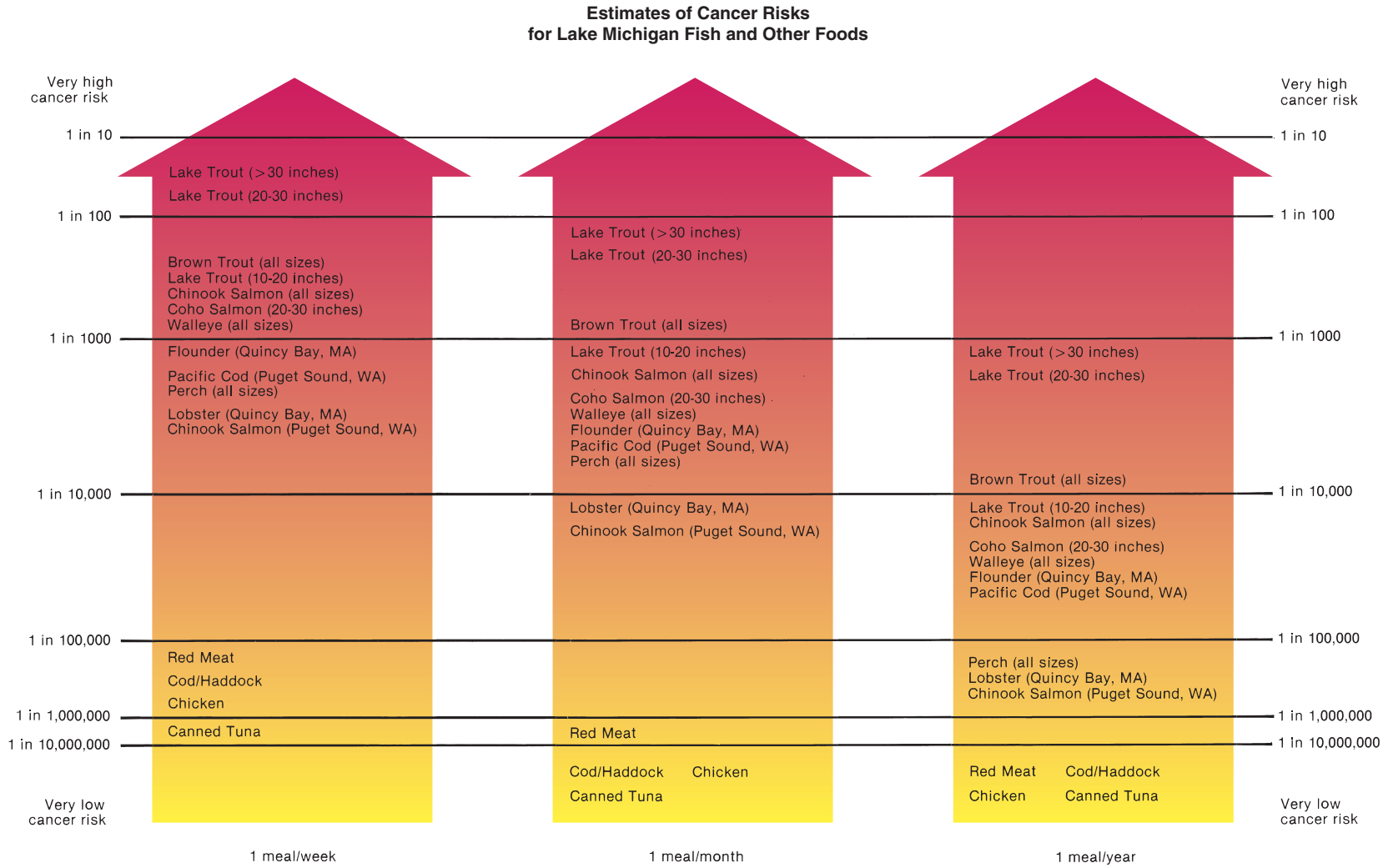


figure 3.2 **Cancer Risk and Fish Consumption** A study by the National Wildlife Federation provides estimates for cancer risks associated with the consumption of sport fish.

ENVIRONMENTAL CLOSE-UP

What's in a Number?

Risk values are often stated, shorthand-fashion, as a number. When the risk concern is cancer, the risk number represents a probability of occurrence of additional cancer cases. For example, such an estimate for Pollutant X might be expressed as 1×10^{-6}, or simply 10^{-6}. This number can also be written as 0.000001, or one in a million—meaning one additional case of cancer projected in a population of one million people exposed to a certain level of Pollutant X over their lifetimes. Similarly, 5×10^{-7}, or 0.0000005, or five in *100 million,* indicates a potential risk of five additional cancer cases in a population of 100 million people exposed to a certain level of the pollutant. These numbers signify incremental cases above the background cancer incidence in the general population. American Cancer Society statistics indicate that the background cancer incidence in the general population is one in three over a lifetime.

If the effect associated with Pollutant X is not cancer but another health effect, perhaps neurotoxicity (nerve damage) or birth defects, then numbers are not typically given as probability of occurrence, but rather as levels of exposure estimated to be without harm. This often takes the form of a reference dose (RfD). An RfD is typically expressed in terms of milligrams (of pollutant) per kilogram of body weight per day, e.g., 0.004 mg/kg/day. Simply described, an RfD is a rough estimate of daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious noncancerous effects during a lifetime. The uncertainty in an RfD may be one or several orders of magnitude (i.e., multiples of 10).

What's in a number? The important point to remember is that the numbers by themselves don't tell the whole story. For instance, even though the numbers are identical, a cancer risk value of 10^{-6} for the "average exposed person" (perhaps someone exposed through the food supply) is not the same thing as a cancer risk of 10^{-6} for a "most exposed individual" (perhaps someone exposed from living or working in a highly contaminated area). It's important to know the difference. Omitting the qualifier "average" or "most exposed" incompletely describes the risk and would mean a failure in risk communication.

A numerical estimate is only as good as the data it is based on. Just as important as the *quantitative* aspect of risk characterization (the risk numbers), then, are the *qualitative* aspects. How extensive is the data base supporting the risk assessment? Does it include human epidemiological data as well as experimental data? Does the laboratory data base include less data on more than one species? If multiple species were tested, did they all respond similarly to the test substance? What are the "data gaps," the missing pieces of the puzzle? What are the scientific uncertainties? What science policy decisions were made to address these uncertainties? What working assumptions underlie the risk assessment? What is the overall confidence level in the risk assessment? All of these qualitative considerations are essential to deciding what reliance to place on a number and to characterizing a potential risk.

Source: Data from *EPA Journal.*

doses are used. Human exposure is likely to be lower or infrequent. Because of all these uncertainties, government regulators have decided to err on the side of safety to protect the public health. That approach has been criticized by those who say it carries protection to the extreme, usually at the expense of industry.

Over the past decade, risk assessment has had its largest impact in regulatory practices involving cancer-causing chemicals called **carcinogens.** In the United States, for example, the decisions to continue registration of pesticides, to list substances as hazardous air pollutants under the Clean Air Act, and to regulate water contaminants under the Safe Drinking Water Act depend to a large degree on the risk assessments for the substances in question.

Risk assessment analysis is also being used to help set regulatory priorities and support regulatory action. Those chemicals or technologies that have the highest potential to cause damage to health or the environment receive attention first, while those perceived as having minor impacts receive less immediate attention. Medical waste is perceived as having high risk, and laws have been enacted to minimize the risk, while the risk associated with the use of fertilizer on lawns is considered minimal and is not regulated.

The science supporting environmental regulatory decisions is complex and rapidly evolving. Many of the most important threats to human health and the environment are highly uncertain. Risk assessment quantifies risk and states the uncertainty that surrounds many environmental issues. This can help institutions research and plan in a way that is consistent with scientific and public concern for environmental protection.

Risk Management

Risk management is a decision-making process that involves risk assessment, technological feasibility, economic impacts, public concerns, and legal requirements. Risk management includes:

1. Deciding which risks should be given the highest priority
2. Deciding how much money will be needed to reduce each risk to an acceptable level
3. Deciding where the greatest benefit would be realized by spending limited funds
4. Deciding how much risk is acceptable
5. Deciding how the plan will be enforced and monitored

Risk management raises several issues. With environmental concerns such

Table 3.1 Risks of Death

Deaths per million hours of exposure	
Mountain climbing	40,000
Canoeing	10,000
Cigarette smoking	3000
Swimming	2560
Automobile travel	1200
Hunting	1000
Air travel	500
Being struck by lightning	100
Vaccination	1.5
Living beside a nuclear power plant	0.5

as acid rain, ozone depletion, and hazardous waste, the scientific basis for regulatory decisions is often controversial. As was previously mentioned, hazardous substances can be tested, but only on animals. Are animal tests appropriate for determining impacts on humans? There is not an easy answer to this question. Dealing with global warming, ozone depletion, and acid rain require projecting into the future and estimating the magnitude of future effects. Will the sea level rise? How many lakes will become acidified? How many additional skin cancers will be caused by depletion of the ozone layer? Estimates from equally reputable sources vary widely. Which ones do we believe?

The politics of risk management frequently focus on the adequacy of the scientific evidence. The scientific basis can be thought of as a kind of problem definition. Science determines that some threat or hazard exists, but because scientific facts are open to interpretation, there is controversy. For example, it is a fact that dioxin is a highly toxic material known to cause cancer in laboratory animals. It is also very difficult to prove that human exposure to dioxin has led to the development of cancer, although high exposures have resulted in acne in exposed workers. Acne is a common result of exposure to molecules like dioxin.

This is why problem definition is so important. Defining the problem helps to determine the rest of the policy process (making rules, passing laws, or issuing statements). If a substance poses little or no risk, then policy action is unnecessary. For example, some observers believe chemicals pose many threats that need to be addressed. Others believe chemicals pose little threat; instead, they see scare tactics and government regulations as unnecessary attacks on businesses. Logging forests poses risks of soil erosion and the loss of resident animal species. The timber industry sees these risks as minimal and as a threat to its economic well-being, while many environmentalists consider the risks unacceptable. These and similar disagreements are often serious public-relations problems for both government and business because most of the public has a poor understanding of the risks they accept daily.

True and Perceived Risks

People often overestimate the frequency and seriousness of dramatic, sensational, well-publicized causes of death and underestimate the risks from more familiar causes that claim lives one by one. Risk estimates by "experts" and by the "public" on many environmental problems differ significantly. This discrepancy and the reasons for it are extremely important because the public generally does not trust experts to make important risk decisions alone.

While public health and environmental risks can be minimized, eliminating all risks is impossible. Almost every daily activity—driving, walking, working—involves some element of risk. (See table 3.1.)

From a risk management standpoint, whether one is dealing with a site-specific situation or a national standard, the deciding question ultimately is: What degree of risk is acceptable? In general, we are not talking about a "zero risk" standard, but rather a concept of **negligible risk:** At what point is there really no significant health or environmental risk? At what point is there an adequate safety margin to protect public health and the environment?

Risk management involves comparing the estimated true risk of harm from a particular technology or product with the risk of harm perceived by the general public. The public generally perceives involuntary risks, such as nuclear power plants or nuclear weapons, as greater than voluntary risks, such as drinking alcohol or smoking. In addition, the public perceives newer technologies, such as genetic engineering or toxic-waste incinerators, as greater risks than more familiar technologies, such as automobiles and dams. Many people are afraid of flying for fear of crashing; however, automobile accidents account for a far greater number of deaths—about 45,000 in the United States each year, compared to less than a thousand annually from plane crashes. (See figure 3.3.)

A fundamental problem facing governments today is how to satisfy people who are concerned about a problem that experts state presents less hazard than another less visible problem, especially when economic resources to deal with the problems are limited. Debate continues over the health concerns raised by asbestos, dioxin and radon.

Some researchers argue that the public is frequently misled by the politics of public health and environmental safety. This is understandable since many prominent people become involved in such issues and use their public image to encourage people to look at issues from a particular point of view.

Whatever the issue, it is hard to ignore the will of the people, particularly when sentiments are firmly held and not easily changed. A fundamental issue surfaces concerning the proper role of a democratic government and other organizations in a democracy when it comes

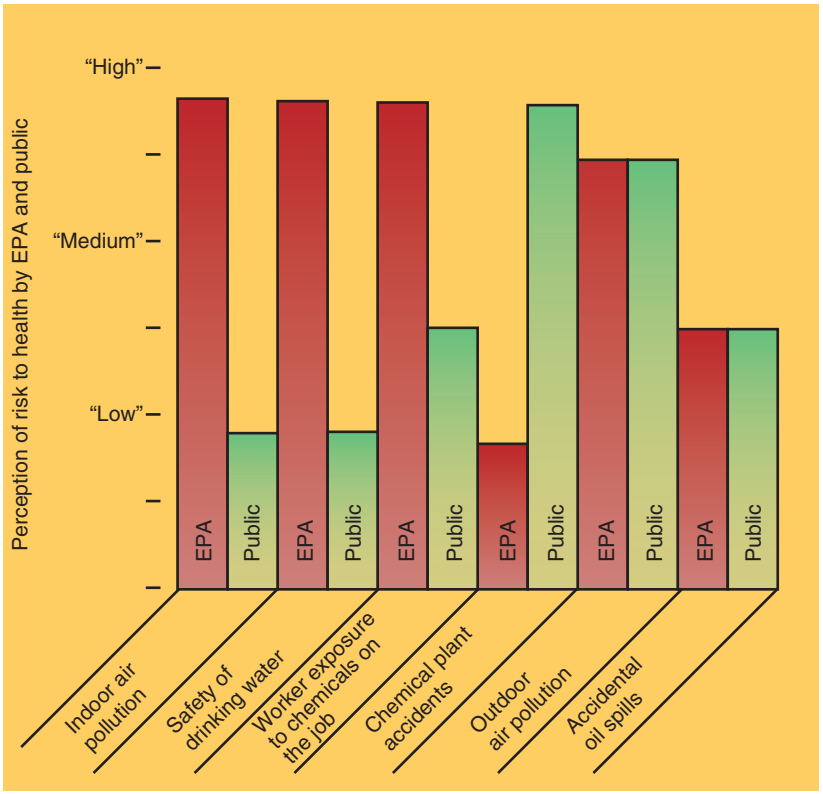


figure 3.3 **Perception of Risk** Professional regulators and the public do not always agree on what risks are.

to matters of risk. Should the government focus available resources and technology where they can have the greatest tangible impact on human and ecological well-being, or should it focus them on problems about which the public is most upset? What is the proper balance? For example, adequate prenatal health care for all pregnant women would have a greater effect on the health of children than would removing asbestos from all school buildings.

Obviously, there are no clear answers to these questions. However, experts and the public are both beginning to realize that they each have something to offer concerning how we view risk. Many risk experts who have been accustomed to looking at numbers and probabilities are now conceding that there is rationale for looking at risk in broader terms. At the same time, the public is being supplied with more data to enable them to make more informed judgments.

Throughout this discussion of risk assessment and management we have made numerous references to costs and economics. It is not economically possible to eliminate all risk. As risk is eliminated, the cost of the product or service increases. Many environmental issues are difficult to evaluate from a purely economic point of view, but economics is one of the tools useful to analyzing any environmental problems.

Economics and the Environment

Environmental problems are primarily economic problems. While this may be an overstatement, it often is difficult to separate economics from environmental issues or concerns. Basically, economics deals with resource allocation. It is a description of how we value goods and services. We are willing to pay for things or services we value highly and are unwilling to pay for things we think there is plenty of. For example, we will readily pay for a warm, safe place to live but would be offended if someone suggested that we pay for the air we breathe.

Our goal as a society is to seek long-term economic growth that creates jobs while improving and sustaining the environment. Achieving this goal requires an environmental strategy that repairs past environmental damage; helps us shift from waste management to pollution prevention; and uses valuable resources more efficiently.

In the three decades since the first Earth Day, many nations have made considerable progress in responding to threats to public health and the environment. Yet major challenges remain. We can put in place a set of policies and programs that will establish a new course for the development and use of environmental technologies into the next century. We must, however, broaden our environmental tool kit, replacing those instruments that are no longer effective with a new set of tools designed to meet today's challenges and tomorrow's needs.

Economic Concepts

An economic good or service can be defined as anything that is scarce. Scarcity exists whenever the demand for anything exceeds its supply. We live in a world of general scarcity. **Resources** are anything that contributes to making desired goods and services available for consumption. Resources are limited, relative to the desires of humans to consume. The **supply** is the amount of a good or service available to be purchased. **Demand** is the amount of a product that consumers are willing and able to buy at various prices. In economic terms, supply depends on:

1. The raw materials available to produce a good or service using present technology
2. The amounts of those materials available
3. The costs of extracting, shipping, and processing the raw materials

4. The degree of competition for those materials among users
5. The feasibility and cost of recycling already used material
6. The social and institutional arrangements that might have an impact. (See figure 3.4.)

The relationship between available supply of a commodity or service and its price is known as a **supply/demand curve.** (See figure 3.5.) The price of a product or service reflects the strength of the demand for and the availability of the commodity. When demand exceeds supply, the price rises. Cost increases cause people to seek alternatives or to decide not to use a product or service, which results in lower quantity demanded.

For example, food production depends heavily on petroleum for the energy to plant, harvest, and transport food crops. In addition, petrochemicals are used to make fertilizer and chemical

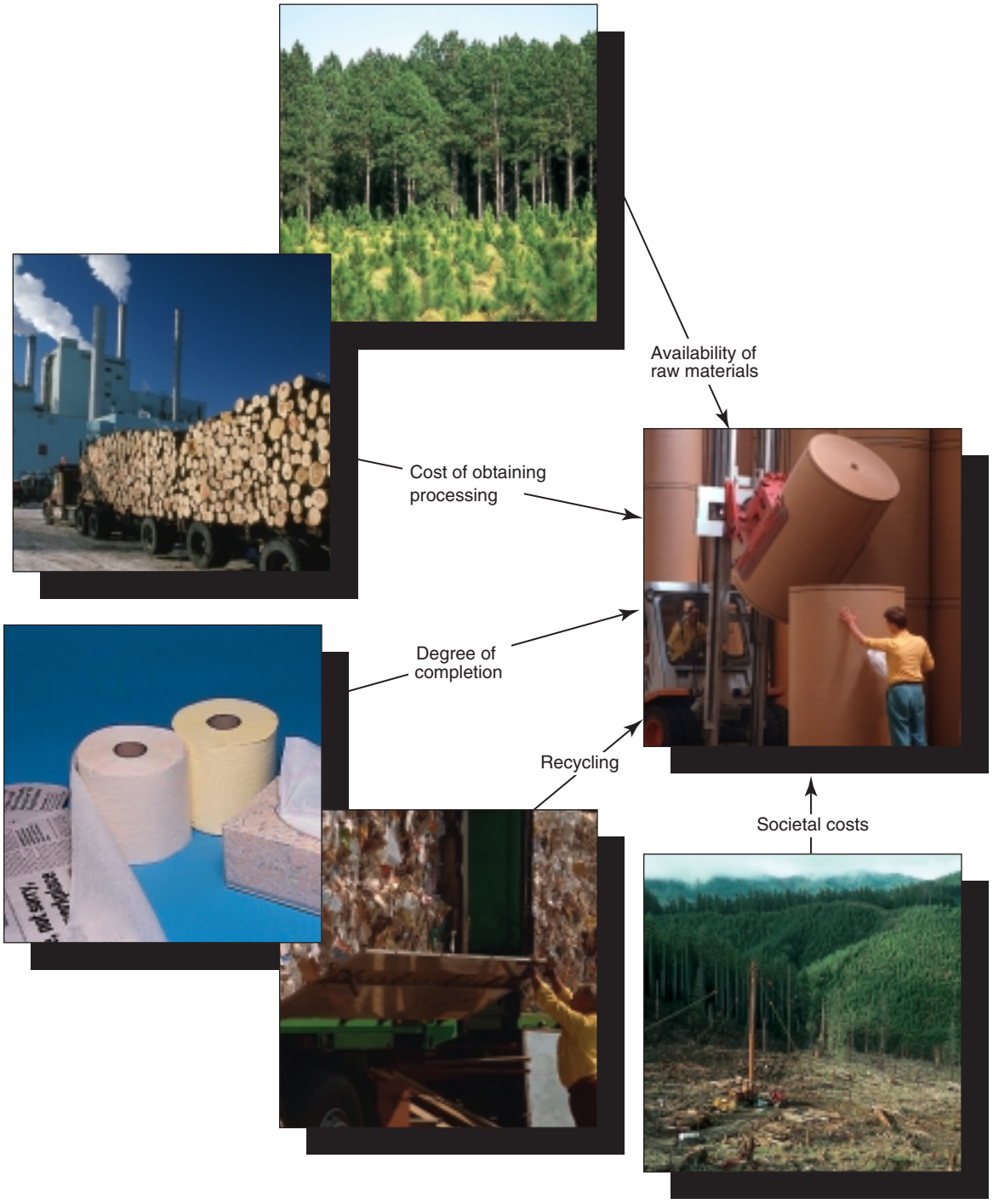


figure 3.4 **Factors that Determine Supply** The supply of a good or service is dependent on the several factors shown here.

pest-control agents. As petroleum prices rise, farmers reduce their petroleum use. Perhaps they farm less land or use less fertilizer or pesticide. Regardless, the price of food must rise as the price of petroleum rises. As the prices of certain foods rise, consumers seek less costly forms of food.

When the supply of a commodity exceeds the demand, producers must lower their prices to get rid of the product, and eventually, some of the producers go out of business. Ironically, this happens to farmers when they have a series of good years. Production is high, prices fall, and some farmers go out of business.

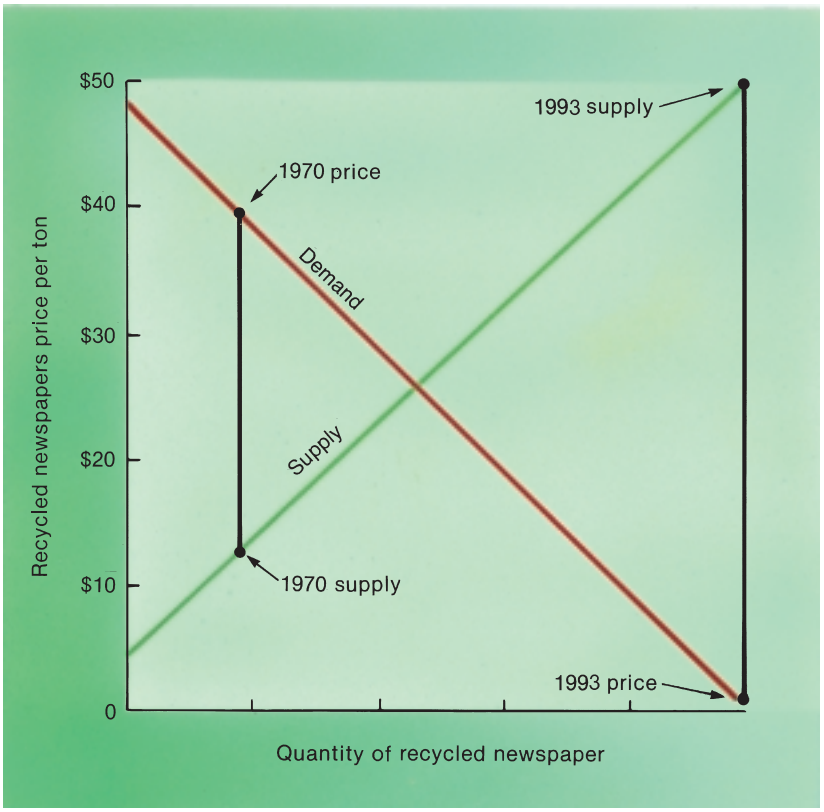
Market-Based Instruments

With the growing interest in environmental protection during the past decade, policy makers are examining new methods to reduce harm to the environment. One area of growing interest is market-based instruments (MBIs). MBIs provide an alternative to the common command-and-control legislation because they use economic forces and the ingenuity of entrepreneurs to achieve a high degree of environmental protection at a low cost. Instead of dictating how industry should conduct its activities, MBIs provide incentives by imposing costs on pollution-causing activities. This approach allows companies to decide for themselves how best to achieve the required level of environmental protection. To date, most of these market-based policies have been implemented in developed nations and in some rapidly growing developing nations. In virtually all cases, they have been introduced as supplements to, not substitutes for, traditional government regulations.

Implementing market-based policies is not easy in any nation. To succeed, nations optimally require open, dynamic market systems, sound macroeconomic conditions, political and institutional stability, and full development of human rights.

In developing nations with large informal sectors, other policies—capacity-building, overall policy reform, community participation, investments in education and health care—initially may be more effective than market-based mechanisms.

Nevertheless, market-based policies may offer valuable opportunities to achieve environmental goals more efficiently and at lower cost to governments and entrepreneurs. They also offer opportunities for governments to ride the momentum of economic growth, while leading it to a more sustainable footing.



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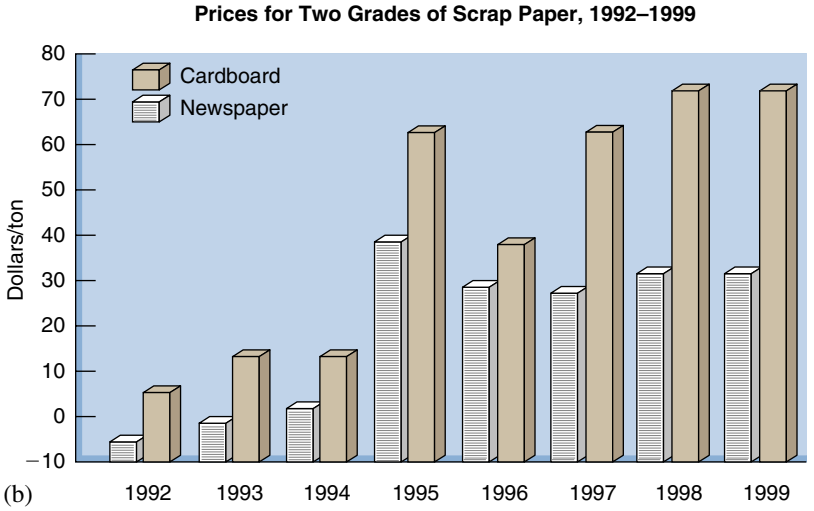


(b)

figure 3.5 **Supply and Demand** *(a)* As a result of increased interest in recycling, the supply of recycled newspapers has increased substantially between 1970 and 1993. The demand changed very little; therefore, the price in 1993 was extremely low. *(b)* Beginning in 1994, the demand for recycled newspaper and cardboard increased, thus the price rose significantly. Prices were more stable through 1999.

Source: *(b)* Data from *Recycling Times.*

Market-based instruments acknowledge the fact that environmental resources are often underpriced. First, subsidies—on water, electricity, fossil fuels, road transport, and agriculture—are an incentive to overuse a resource; reducing or removing subsidies creates an incentive to use resource more efficiently. Second, market prices reflect only private cost, not the external damages caused by pollution or resource extraction. Instead of inflexible, top-down government directives, market-based policies take advantage of price signals and give entrepreneurs the freedom to choose the solution most economically efficient for them.

MBIs can be grouped into five basic categories:

1. **Information programs**

   These programs rely on informed consumers' market choices to reduce environmental problems. Information about the environmental or risk consequences of choices make clear to consumers that it is in their personal interest to change their decisions or behavior. Examples include radon or lead testing or labeling pesticide products. Another type of program, such as the Toxic Release Inventory in the United States, discloses information on environmental releases by polluters. This provides corporations with incentives to improve their environmental performance to enhance their public image.

2. **Tradable emissions permits**

   These permits give companies the right to emit specified quantities of pollutants. Companies that emit less than the specified amounts can sell their permits to other firms or "bank" them for future use. Businesses responsible for pollution have an incentive to internalize the external cost they were previously imposing on society: If they clean up their pollution sources, they can realize a profit by selling their permit to pollute. Once a business recognizes the possibility of selling its permit, it sees that pollution is not costless. The creation of new markets (the permits) to reduce pollution reduces the external aspects to waste disposal and makes them internal costs, just like costs of labor and capital.

3. **Emission fees, taxes, and charges**

   These fees provide incentives for environmental improvement by making environmentally damaging activity or products more expensive. Businesses and individuals reduce their level of pollution wherever it is cheaper to abate the pollution than to pay the charges. Emissions fees can be useful when pollution is coming from many small sources, such as vehicular emissions or agricultural runoff, where direct regulation or trading schemes are impractical. Taxes contribute to government revenue; charges are used to fund environmental cleanup programs.

   In China, a pollution tax system is intended to raise revenue for investment in industrial pollution control, help pay for regulatory activities, and encourage enterprises to comply with emission and effluent standards. The system imposes noncompliance fees on discharges that exceed standards, and fines and other charges assessed on violations of regulations.

   In the Netherlands, a system of effluent charges on industrial wastewater has been viewed as successful. Especially among larger companies, the tax worked as an incentive to reduce pollution. In a survey of 150 larger companies, about two-thirds said the tax was the main factor in their decision to reduce discharges. As the volume of pollution from industrial sources dropped, rates were increased to cover the fixed costs of sewage water treatment plants. Rising rates are providing a further incentive for more companies to start purifying their sewage water.

4. **Performance Bond/Deposit-refund programs**

   These programs place a surcharge on the price of a product, which is refunded when the used product is returned for reuse or recycling.

   Some nations—including Indonesia, Malaysia, and Costa Rica—use performance bonds to ensure that reforestation takes place after timber harvesting.

   The United States also has used this kind of approach to ensure that strip-mined lands are reclaimed. Before a mining permit can be granted, a company must post a performance bond sufficient to cover the cost of reclaiming the site in the event the company does not complete reclamation. The bond is not fully released until all performance standards have been met and full reclamation of the site, including permanent revegatation, is successful—a five-year period in the East and Midwest and 10 years in the arid West. The bond can be partially released as various phases of reclamation are successfully completed.

   Deposit/refund schemes have been widely used to encourage recycling. In Japan, deposits are made for the return of bottles. The deposits are passed on from manufacturers to shops and ultimately consumers, who get the deposit refunded when the used packages and bottles are returned. Under this system, Japan recycled 92 percent of its beer bottles, 50 percent of waste paper, 43 percent of aluminum cans, and 48 percent of glass bottles.

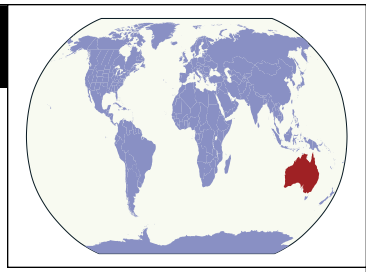
5. **Subsidies**

   Subsidies may include consumer rebates for purchases of environmentally friendly goods, soft loans for businesses planning to implement environmental products, and other monetary incentives designed to reduce the costs of improving environmental performance.

A **subsidy** is a gift from government to a private enterprise that is considered important to the public interest. Agriculture, transportation, space technology, and communication are frequently subsidized by governments. These gifts, whether loans, favorable tax situations, or direct grants, are all paid for by taxes on the public.

GLOBAL PERSPECTIVE

Wombats and the Australian Stock Exchange



The global New Economy can soon claim platypuses, wombats, numbats, and wallabies among its most charismatic recent recruits.

These native Australian mammals, at risk from the steady loss of their habitat, are working assets of Earth Sanctuaries Ltd., which is taking a controversial new approach to environmental activism. In 2000, Earth Sanctuaries was listed on the Australian Stock Exchange, making it the world's first conservation company to go public.

The venture, which makes money mostly from tourists attracted by access to rare animals at three Australian sanctuaries, is considered an extreme example of a trend intriguing environmentalists and investors around the world. Many believe calls to altruism have failed to reverse the rapid loss of species. It's time, they say, to focus on the bottom line.

There is however a growing debate to this new approach. On the one side, researchers see this approach as a beautiful alignment of incentives. They would argue that people care first of all about themselves and their families, and it just has not worked to try to make them choose. Do you save to give your daughter a good education or help rescue a marsupial? They argue that this way you can have both.

Yet some worry about the fund-raising approach. Their argument would be that there would always be a tension between conservation and maximizing profits. If shareholders pressure the company to make higher returns, will the company compromise its values by building megalodges or overstocking the reserves? Some would raise the question, is this approach really conserving natural ecosystems or just creating large zoos?

Is this argument purely idealistic or accurate? Does the market place have a role in habitat preservation? Are there other applications of this approach that you can identify?

Subsidies are costly in two ways: First, the bureaucracy necessary to administer a subsidy costs money, and the subsidy is an indirect way of keeping the market price of a product low. The actual cost is higher because these subsidy costs must be added to the market price to arrive at the product's true cost. Second, in many cases, subsidies encourage activities that in the long term may be detrimental to the environment. For example, the transportation subsidies for highway construction encourage use of inefficient individual automobiles. Higher taxes on automobile use to cover the cost of building and repairing highways would encourage the use of more energy-efficient public transport. Most nations are moving toward reduction of subsidies in many areas, bringing the cost of delivering resources such as water and electricity much closer to market cost. Nevertheless, estimated subsidies for energy, roads, water, and agriculture in developing and transition economies still totaled about $250 billion annually by the late 1990s.

Once established, resource subsidies are understandably difficult to dislodge. But experience suggests that subsidies can be reduced or removed without disrupting rural economic development. In China, subsidy rates for coal declined from an estimated 61 percent in 1985 to 10 percent in 1997. Private mines now account for about half of all production and some 80 percent of the coal is now sold at international prices. These reforms have had numerous benefits. Energy intensity in China has fallen by about 50 percent since 1980, operating losses at state-owned mines dropped from $1.4 billion to $230 million over the 1990–95 period, and the government's total subsidy for fossil fuels fell from about $25 billion in 1990/91 to $10 billion in 1997/98.

Land use subsidies also can create perverse incentives. In France, since the mid-nineteenth century, a tax on undeveloped land had encouraged conversion of environmentally sensitive woodlands and wetlands. Under reforms introduced in 1992, this tax has been reduced and the economic incentive to convert less productive natural areas into productive lands decreased.

While research is still needed to determine how MBIs should be structured and used, there has been sufficient experience to justify their further deployment as a means of attaining environmental objectives at least possible cost. Successful programs so far include a sulfur dioxide trading market, lead phasedown banking and trading, and hundreds of pay-by-the-bag trash collection programs in many countries.

When used correctly, market-based approaches will allow us to reach a level of environmental protection at lower total cost than would be possible with the traditional means of command and control. Market forces tend to drive decisions toward least-cost solutions. Offer the right incentives, and business will develop and adopt better pollution-control technology, rather than stagnating at "commanded" technology.

Market-oriented policies, however, will not always work. It could also be stated that no single one of these economic incentive approaches will be a panacea for all problems. It could be a mistake to start with a policy instrument, then go in search of applications. But this kind of flexible approach, using several solutions, is gaining favor among the regulated and the regulators.

Although the various economic instruments discussed have their own niches, they can be used effectively in combination. For example, trading or pricing approaches work better if supported by information programs: communities that adopted pay-by-the-bag systems of trash disposal had fewer problems if households were given adequate information well in advance. Environmental tax systems can incorporate trading features (e.g., taxes can be levied on net emissions after trades). It will be

ENVIRONMENTAL CLOSE-UP

Georgia-Pacific Corporation: Recycled Urban Wood—A Case Study in Extended Product Responsibility

Georgia-Pacific manufactures particleboard from multi-species wood recovered from commercial disposal or general urban solid waste. The company has agreements with five recycling and processing companies that accept or collect wood at various sites. The wood is cleaned of contaminants and sent to a Georgia-Pacific particleboard manufacturing plant in Martell, California, or to other end users.

The project involves five stakeholder groups: (1) wood waste producers (e.g., operations involved with construction and demolition debris, cut-to-size lumber, commercial wood waste from furniture), (2) collection agents, (3) processors of wood waste, which make the waste into a product that can be reused, (4) transportation contractors, shippers, and haulers, and (5) end users (e.g., Georgia-Pacific's Martell plant). The project has a variety of goals, including increasing the availability of the wood supply for particleboard production, contributing to Georgia-Pacific's goals of product stewardship, and contributing to California's mandated reduction in solid waste (e.g., 50 percent reduction by 2002).

Business factors driving the project include the shortage of fiber for the particleboard plant, rising costs of landfilling, and mandated solid waste reductions. Benefits include an expanded fiber supply in the Northwest United States. Contamination is one of the most significant barriers to the wood recovery program. Often the collected wood is mixed in with metal, plastic, and paper and must be cleared of these contaminants to be usable. The captured paper, plastic, and nonferrous metals are sent to a landfill. Wood by-products that cannot be used in particleboard processing are sold for use as animal bedding, playground cover, soil additive, and lawn or garden mulch. Currently virgin fiber, a by-product from sawmills is often less expensive than recovered fiber for use in particleboard. As wood becomes more scarce, however, the economics will reverse.

increasingly important to use the various MBI methods together. The challenge is to design the most appropriate instruments to deal with environmental problems, bearing in mind the relevant policy objectives: steady progress in reducing risks, cost-effectiveness, encouragement of technological innovation, fairness, and administrative simplicity.

Extended Product Responsibility

Extended product responsibility (EPR) is an emerging principle for a new generation of pollution prevention policies that focus on product systems instead of production facilities. It relies for its implementation on life cycle analysis to identify opportunities to prevent pollution and reduce resource and energy use in each stage of the product chain through changes in product design and process technology. All factors along the product chain share responsibility for the life cycle environmental impacts of products, from the upstream impacts inherent in selection of materials and impacts from the manufacturing process itself to downstream impacts from the use and disposal of the products. (See figure 3.6.)

EPR had its origins in Western Europe. The term *extended product responsibility* is derived from the term *extended producer responsibility,* which is often applied to the German packaging ordinance and similar policies in other Western European countries. The second term is something of a misnomer, however, because most extended responsibility schemes allocate the burden of environmental protection all along the product chain rather than placing it entirely on producers. Under the German packaging ordinance, for instance, consumers, retailers, and packaging manufacturers all share this responsibility, with the financial burden of waste management falling on the last two. In the United States, extended product responsibility has gained greater currency because it highlights systems of shared responsibility.

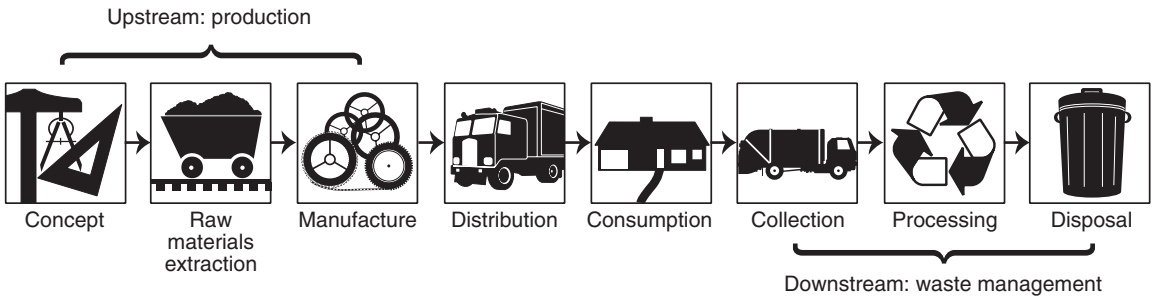


figure 3.6 **The Life Cycle of a Typical Product**

Source: *Environment,* Vol. 39, No. 7, September 1997.

Specific benefits of EPR include:

Cost savings, particularly through the process of producers taking back used products, allow manufacturers to recover valuable materials, reuse them, and save money.

Companies are looking at designing for recycling and disassembly—innovations necessitated by end-of-life management of products, which in many cases helps companies realize how to assemble products more efficiently.

There are more efficient environmental protections, since product-based environmental strategies often are a more cost-effective method of complying with environmental regulations and avoiding environmental liabilities than existing facility-based programs.

Despite these benefits, however, obstacles to EPR exist. These include:

Cost of EPR

Lack of information and tools to assess overall product system impacts

Difficulty in building relationships among actors in different life cycle stages

Hazardous waste regulations that require hazardous waste permits for collection and take-back of certain products

Antitrust laws that make it difficult for companies to cooperate

These are the kinds of questions that further explorations of EPR and, most important, that real-world experience with EPR programs can help to understand and address. Ultimately, EPR is an opportunity to explore new models of environmental policy that are less costly and more flexible.

Cost-Benefit Analysis

People use **cost-benefit analysis** to determine whether a policy generates more social costs than social benefits, and if benefits outweigh costs, how much activity would obtain optimal results. Steps in cost-benefit analysis include:

1. Identification of the project to be evaluated
2. Determination of all impacts, favorable and unfavorable, present and future, on all of society
3. Determination of the value of those impacts, either directly through market values or indirectly through price estimates
4. Calculation of the net benefit, which is the total value of positive impacts less the total value of negative impacts

For example, the cost of reducing the amount of lead in drinking water in the United States to acceptable limits is estimated to be about $125 million a year. The benefits to the nation's health from such a program are estimated at nearly $1 billion per year. Thus under a cost-benefit analysis, the program is economically sound. Recycling of solid waste, which was once cost-prohibitive, is now cost-effective in many communities because the costs of landfills have risen dramatically. Table 3.2 gives examples of the kinds of costs and benefits

Table 3.2 Costs and Benefits of Improving Air Quality

Costs	Benefits
Installation and maintenance of new technology	Reduced deaths and disease
1. Scrubbers on smokestacks	Fewer respiratory problems
2. Automobile emissions control	Reduced plant and animal damage
Redesign of industries and machines	Lower cleaning costs for industry and public
Additional energy costs to industry and public	More clear, sunny days; better visibility
Retraining of employees to use new technology	Less eye irritation
Costs associated with monitoring and enforcement	Fewer odor problems

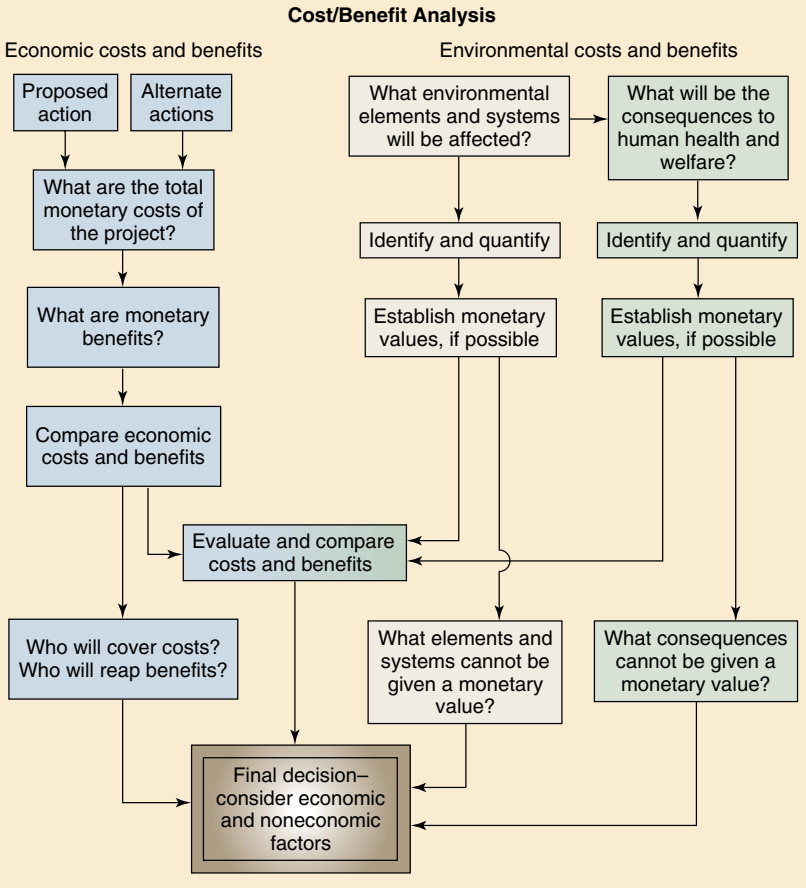


figure 3.7 **Does Everything Have an Economic Value?** The use of water and land is often based on the economic benefits obtained. Anything that humans value creates economic benefits—they just are not all easy to measure.

involved in improving air quality. Although not a complete list, the table indicates the kinds of considerations that go into a cost-benefit analysis. Some of these are easy to measure in monetary terms; others are not.

Concerns about the Use of Cost-Benefit Analysis

Does everything have an economic value? Critics of cost-benefit analysis raise this point, among others. Some people argue that, if economic thinking pervades society, many simple noneconomic values like beauty or cleanliness can survive only if they prove to be "economic." (See figure 3.7.)

It has long been the case in many developed countries that major projects, especially those undertaken by the government, require some form of cost-benefit analysis with respect to environmental impacts and regulations. In the United States, for example, such requirements were established by the National Environmental Policy Act of 1969, which requires environmental impact statements for major government-supported projects. Increasingly, similar analyses are required for projects supported by national and international lending institutions such as the World Bank.

There are clearly benefits to requiring such analysis. Although environmental issues must be considered at some point during project evaluation, efforts to do so are hampered by the difficulty of assigning specific value to environmental resources. In cases of Third World development projects, these already difficult environmental issues are made more difficult by cultural and socioeconomic differences. A less-developed country, for example, may be less inclined to insist on or be able to afford expensive emissions-treatment technology on a project that will provide jobs and economic development.

One particularly compelling critique of cost-benefit analysis is that for analysis to be applied to a specific policy, the analyst must decide which preferences count—that is, which preferences have "standing" in cost-benefit analysis. In theory, cost-benefit analysis should count all benefits and costs associated with the policy under review, regardless of who benefits or bears the costs. In practice, however, this is not always done. For example, if a cost is spread thinly over a great many people, it may not be recognized as a cost at all. The cost of air pollution in many parts of the world could fall into such a category. Debates over how to count benefits and costs for future generations, inanimate objects such as rivers, and nonhumans, such as endangered species, are also common.

Economics and Sustainable Development

The most commonly used definition of the term **sustainable development** is one that originated with the 1987 report, *Our Common Future,* by the World Commission on Environment and Development (known as the Bruntland Commission). By that formulation, sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

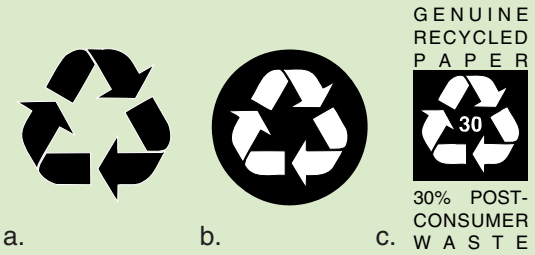
Since the release of the Bruntland Commission report, the phrase has been broadened and modified. The term "sustainable" has gained usage because of increasing concern over exploitation of natural resources and economic devel-

ENVIRONMENTAL CLOSE-UP

"Green" Advertising Claims—Points to Consider

Like many consumers, you may be interested in buying products that are less harmful to the environment. You have probably seen products with such "green" claims as "environmentally safe," "recyclable," "degradable," or "ozone friendly." But what do these claims really mean? How can you tell which products really are less harmful to the environment? Here are some pointers to help you decide.

1. Look for environmental claims that are specific. Read product labels to determine whether they have specific information about the product or its packaging. For example, if the label says "recycled," check how much of the product or packaging is recycled. Labels with "recyclable" claims mean that these products can be collected and made into useful products. This is relevant to you, however, only if this material is collected for recycling in your community or if you can find a way to send the material for recycling.
2. Be wary of overly broad or vague environmental claims. These claims provide little information to help you make purchasing decisions. Labels with unqualified claims that a product is "environmentally friendly," "eco-safe," or "environmentally safe" have little meaning, for two reasons. First, all products have some environmental impact, though some may have less impact than others. Second, these phrases alone do not provide the specific information needed to compare products and packaging on their environmental merits.
3. Some products claim to be "degradable." Degradable materials will not help save landfill space. Biodegradable materials, like food and leaves, break down and decompose into elements found in nature when exposed to air, moisture, and bacteria or other organisms. Photodegradable materials, usually plastics, disintegrate into smaller pieces when exposed to enough sunlight. Either way, however, degradation of any material occurs very slowly in landfills, where most solid waste is sent. That is because modern landfills are designed to minimize the entry of sunlight, air, and moisture. Even organic materials like paper and food may take decades to decompose in a landfill.



Three types of recycling symbols are commonly used in the United States. *(a)* This symbol simply means that the object is potentially recyclable, not that it has been or will be recycled. *(b)* This symbol indicates that a product contains recycled material, but it does not indicate how much recycled material is in the product (it could be only a very small amount). *(c)* This symbol states explicitly the percentage of recycled content found in the product.

opment at the expense of environmental quality. Although disagreement exists as to the precise meaning of the term beyond respect for the quality of life of future generations, most definitions refer to the viability of natural resources and ecosystems over time, and to maintenance of human living standards and economic growth. The popularity of the term stems from the melding of the dual objectives of environmental protection and economic growth. A sustainable agricultural system, for example, can be defined as one that can indefinitely meet the demands for food and fiber at socially acceptable economic costs and environmental impacts.

Finally, as pointed out by Tan Sri Razali, former chairman of the United Nation's Commission on Sustainable Development, the transfer of modern, environmentally sound technology to developing nations is the "key global action to sustainable development."

The past president of the Japan Economic Research Center, Saburo Okita, once stated that a slowdown of economic growth is needed to prevent further deterioration of the environment. Whether or not a slowdown is necessary provokes sharp differences of opinion.

One school of thought argues that economic growth is essential to finance the investments necessary to prevent pollution and to improve the environment by a better allocation of resources. A good school of thought, which is also progrowth, stresses the great potential of science and technology to solve problems and advocates relying on technological advances to solve environmental problems. Neither of these schools of thought sees any need for fundamental changes in the nature and foundation of economic policy. Environmental issues are viewed mainly as a matter of setting priorities in the allocation of resources.

A newer school of economic thought believes that economic and environmental well-being are mutually reinforcing goals that must be pursued simultaneously if either one is to be reached. Economic growth will create its own ruin if it continues to undermine the healthy functioning of Earth's natural systems or to exhaust natural resources. It is also true that healthy economies are most likely to provide the necessary financial investments in environmental protection. For this reason, one of the principal objectives of environmental policy must be to ensure a decent standard of living for all. The

solution, at least in the broad scope, would be for a society to manage its economic growth in such a way as to do no irreparable damage to its environment. The term *sustainable development* has been criticized as ambiguous and open to a wide range of interpretations, many of which are contradictory. The confusion arises because "sustainable growth" and "sustainable use" have been used interchangeably, as if their meanings were the same. They are not. "Sustainable growth" is a contradiction in terms: Nothing physical can grow indefinitely. "Sustainable use" is applicable only to renewable resources: it means using them at rates within their capacity for renewal.

By balancing economic requirements with ecological concerns, the needs of the people are satisfied without jeopardizing the prospects of future generations. While this concept may seem to be common sense, the history of the world shows that it has not been a common practice. A major obstacle to sustainable development in many countries is a social structure that gives most of the nation's wealth to a tiny minority of its people. It has been said that a person who is worrying about his next meal is not going to listen to lectures on protecting the environment. What to residents in the Northern Hemisphere seem like some of the worst environmental outrages—cutting rain forests to make charcoal for sale as cooking fuel, for example—are often committed by people who have no other form of income.

The disparities that mark individual countries are also reflected in the planet as a whole. Most of the wealth is concentrated in the Northern Hemisphere. From the Southern Hemisphere's point of view, it is the rich world's growing consumption patterns—big cars, refrigerators, and climate-controlled shopping malls—that are the problem. The problem for the long term is that people in developing countries now want those consumer items that make life in the industrial world so comfortable—and these are the items that are environmentally so costly. If the standard of living in China and India were to rise to that of Germany or the United States, the environmental impact on the planet would be significant.

figure 3.8 **Indian Deforestation Causes Floods in Bangladesh** Because the Ganges River drains much of India and the country of Bangladesh is at the mouth of the river, deforestation and poor land use in India can result in devastating floods in Bangladesh.

If sustainable development is to become feasible, it will be necessary to transform our approach to economic policy. Steps in that direction would include changing the definition of gross national product (GNP) to include environmental improvement or decline. The concept of sustainable development may seem simple, but implementing it will be a very complex process.

Historically, rapid exploitation of resources has provided only short-term economic growth, and the environmental consequences in some cases have been incurable. For example, 40 years ago, forests covered 30 percent of Ethiopia. Today, forest covers only 1 percent, and deserts are expanding. One-half of India once was covered by trees; today, only 14 percent of the land is in forests. As the Indian trees and topsoil disappear, the citizens of Bangladesh drown in India's runoff. (See figure 3.8.)

Sustainable development requires choices based on values. Both depend upon information and education, especially regarding the economics of decisions that affect the environment. A. W. Clausen, in his final address as president of the World Bank, noted the

> increasing awareness that environmental precautions are essential for continued economic development over the long run. Conservation, in its broadest sense, is not a luxury for people rich enough to vacation in scenic parks. It is not just a motherhood issue. Rather, the goal of economic growth itself dictates a serious and abiding concern for resource management.

High-income developed nations, such as the United States, Japan, and much of Europe, are in a position to promote sustainable development. They have the resources to invest in research and the technologies to implement research findings. Some believe that the world should not impose environmental protection standards upon poorer nations without also helping them move into the economic mainstream.

Gaylord Nelson, the founder of the first Earth Day, lists five characteristics that define sustainability:

1. *Renewability:* A community must use renewable resources, like water, topsoil, and energy sources, no faster than they can replace themselves. The rate of consumption of renewable resources cannot exceed the rate of regeneration.
2. *Substitution:* Whenever possible, a community should use renewable resources instead of nonrenewable resources. This can be difficult, because there are barriers to substitution. To be sustainable, a community has to make the transition before the nonrenewable resources become prohibitively scarce.

Table 3.3 Economic Solutions to Pollution and Resource Waste

Solution	Internalizes External Costs	Innovation	International Competitiveness	Administrative Costs	Increases Government Revenue
Regulation	Partially	Can encourage	Decreased*	High	No
Subsidies	No	Can encourage	Increased	Low	No
Withdrawing harmful subsidies	Yes	Can encourage	Decreased*	Low	Yes
Tradable rights	Yes	Encourages	Decreased*	Low	Yes
Green taxes	Yes	Encourages	Decreased*	Low	Yes
User fees	Yes	Can encourage	Decreased*	Low	Yes
Pollution-prevention bonds	Yes	Encourages	Decreased*	Low	No

*Unless more cost-effective and productive technologies are developed.

3. *Interdependence:* A sustainable community recognizes that it is a part of a larger system and that it cannot be sustainable unless the larger system is also sustainable. A sustainable community does not import resources in a way that impoverishes other communities, nor does it export its wastes in a way that pollutes other communities.
4. *Adaptability:* A sustainable community can absorb shocks and can adapt to take advantage of new opportunities. This requires a diversified economy, educated citizens, and a spirit of solidarity. A sustainable community invests in, and uses, research and development.
5. *Institutional commitment:* A sustainable community adopts laws and political processes that mandate sustainability. Its economic system supports sustainable production and consumption. Its educational systems teach people to value and practice sustainable behavior.

External Costs

Many of the important environmental problems facing the world today arise because modern production techniques and consumption patterns transfer waste disposal, pollution, and health costs to society. Such expenses, whether they are measured in monetary terms or in diminished environmental quality, are borne by someone other than the individuals who use a resource. They are referred to as **external costs.** For example, consider an individual who attempts to spend a day of leisure fishing in a lake. Transportation, food, fishing equipment, and bait for the day's activities can be purchased in readily accessible markets. But suppose that upon arrival at the lake, the individual finds a lifeless, polluted body of water. Let us further suppose that a chemical plant situated on the lakeshore is responsible for degrading the water quality on the lake to the point that all or most of the fish are destroyed. In this example, fishers collectively bear the external costs of chemical production in the form of lost recreational opportunities.

Pollution-control costs include pollution-prevention costs and pollution costs. **Pollution-prevention costs** are those incurred either in the private sector or by government to prevent, either entirely or partially, the pollution that would otherwise result from some production or consumption activity. The cost incurred by local government to treat its sewage before dumping it into a river is a pollution-prevention cost; so is the cost incurred by a utility to prevent air pollution by installing new equipment.

Pollution-prevention costs can often be factored into a life cycle analysis. Life cycle analysis can help us understand the full cost, potential, and impact on new products and their associated technologies. As a systems approach, life cycle analysis examines the entire set of environmental consequences of a product, including those that result from its manufacture, use, and disposal. Because the relationships among industrial processes are complex, life cycle analysis requires understanding of material flows, resource reuse, and product substitution. Shifting to an approach that considers all resources, products, and waste as an interdependent system will take time, but governments can facilitate the shift by encouraging the transition to a systems approach.

Pollution costs can be broken down into two categories:

1. The private or public expenditures to avoid pollution damage once pollution has already occurred
2. The increased health costs and loss of the use of public resources because of pollution

The large cost of cleaning up spills, such as that from the *Exxon Valdez* and from the war in the Persian Gulf, is an example of a pollution cost, as is the increased health risk to humans from eating seafood contaminated from the oil. By the middle 1990s there were several new economic solutions being utilized to both internalize external costs and to prevent pollution. (See table 3.3.)

Common Property Resource Problems

Economists have stated that, when everybody shares ownership of a resource, there is a strong tendency to overexploit and misuse that resource. Thus, common public ownership could

GLOBAL PERSPECTIVE

Pollution Prevention Pays!

Extended product responsibility (EPR) is an emerging principle of resource conservation and pollution prevention. EPR advocates using a life cycle perspective to identify pollution prevention and resource conservation opportunities that maximize eco-efficiency. Under this principle, there is assumed responsibility for the environmental impacts of a product throughout its life cycle, including impacts on the selection of materials for the product, impacts from the manufacturer's production process, and downstream impacts from the use, recycling, or disposal of the product.

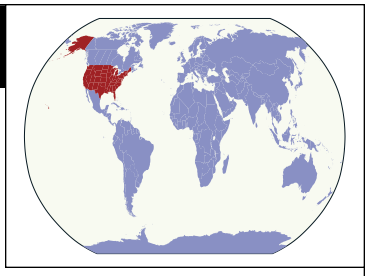
While this concept is relatively new, successful examples of it are in operation. For example, several years ago the Minnesota Mining and Manufacturing (3M) Company's European chemical plant in Belgium switched from a polluting solvent to a safer but more expensive water-based substance to make the adhesive for its Scotch™ Brand Magic™ Tape. The switch was not made to satisfy any environmental law in Belgium or the 12-nation European Community. 3M managers were complying with company policy to adopt the strictest pollution-control regulations that any of its subsidiaries is subject to—even in countries that have no pollution laws at all.

Part of the policy is founded on corporate public relations, a response to growing customer demand for "green" products and environmentally responsible companies. But as many North American multinationals with similar global environmental policies are discovering, cleaning up waste, whether voluntarily or as required by law, can cut costs dramatically.

Since 1975, 3M's "Pollution Prevention Pays" program—or 3P—has cut the company's air, water, and waste pollution around the world in half and, at the same time, has saved nearly $600 million in the last 18 years on changes in its manufacturing process, including $100 million overseas. Less waste has meant less spending to comply with pollution-control laws. But, in many cases, 3M actually has made money selling wastes it formerly hauled away. And, because of recycling prompted by the 3P program, it has saved money by not having to buy as many raw materials.

AT&T followed a similar path. In 1990, it set voluntary goals for the company's 40 manufacturing and 2,500 nonmanufacturing sites worldwide. According to its latest estimates, AT&T has (1) reduced toxic air emissions, many caused by solvents used in the manufacture of computer circuit boards, by 73 percent; (2) reduced emissions of chlorofluorocarbons—gases blamed for destroying the ozone layer in the Earth's atmosphere—by 76 percent; and (3) reduced manufacturing waste 39 percent.

Xerox Corporation had focused on recycling materials in its global environment efforts. It provides buyers of its copiers with free United Parcel Service pickup of used copier cartridges, which contain metal-alloy parts that otherwise would wind up in landfills. The cartridges and other parts are now cleaned and used to make new ones.



Control and Prevention Technologies—Some Examples

Control/Treatment/Disposal

- Sewage treatment
- Industrial wastewater treatment
- Refuse collection
- Incineration
- Off-site recovery and recycling of wastes
- Landfilling
- Catalytic conversion and oxidation
- Particulate controls
- Flue-gas desulfurization
- Nitrogen oxides control technology
- Volatile organic compound control and destruction
- Contaminated site remediation

Prevention

- Improved process control to use energy and materials more efficiently
- Improved catalysis or reactor design to reduce by-products, increase yield, and save energy in chemical processes
- Alternative processes (e.g., low or no-chlorine pulping)
- In-process material recovery (e.g., vapor recovery, water reuse, and heavy metals recovery)
- Alternatives to chlorofluorocarbons and other organic solvents
- High-efficiency paint and coating application
- Substitutes for heavy metals and other toxic substances
- Cleaner or alternative fuels and renewable energy
- Energy-efficient motors, lighting, heat exchangers, etc.
- Water conservation
- Improved "housekeeping" and maintenance in industry

Source: Data from EPA Journal.

Other recycled Xerox copier parts include power supplies, motors, paper transport systems, printed wiring boards, and metal rollers. In all, 1 million parts per year are remanufactured. The initial design and equipment investment was $10 million. Annual savings total $200 million.

The philosophy of pollution prevention is that pollution should be prevented or reduced at the source whenever feasible. It is increasingly being shown that preventing pollution can cut business costs and thus increase profits. Pollution prevention, then, does make cents!

be better described as effectively having no owner.

For example, common ownership of the air makes it virtually costless for any industry or individual to dispose of wastes by burning them. The air-pollution cost is not reflected in the economics of the polluter but becomes an external cost to society. Common ownership of the ocean makes it inexpensive for cities to use the ocean as a dump for their wastes. (See figure 3.9.)

Similarly, nobody owns the right to harvest whales. If any one country delays in getting its share of the available supply of whales, other countries may beat that country to the supply. Thus, there is a strong incentive to overharvest

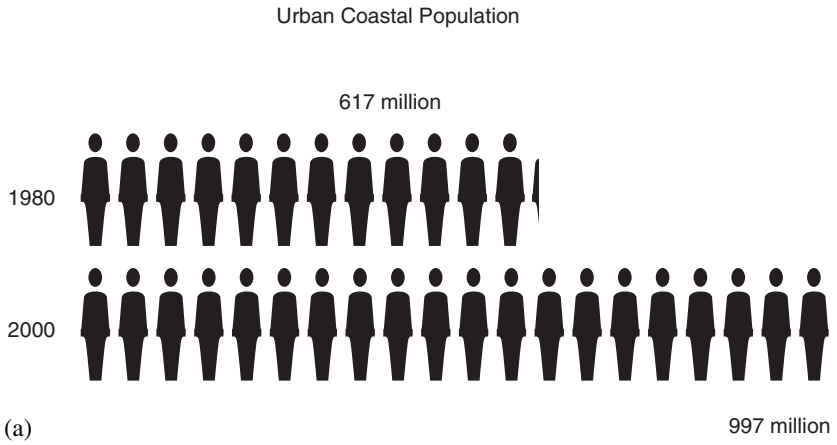


figure 3.9 **Abuse of the Ocean** Since the oceans of the world are a shared resource that nobody owns, there is a tendency to use the resource unwisely. *(a)* Growing population in coastal areas lead to more marine pollution and destruction of coastal habitats. *(b)* Many countries use the ocean as a dump for unwanted trash. Some 6.5 million tons of litter finds its way into the sea each year.

Source: (a) Data from UN Environment Programme; World Resources Institute.

the whale population which creates a consequent threat to the survival of the species. What is true on an international scale for whales is true also for other species within countries. Note that endangered species are wild and undomesticated; the survival of privately owned livestock is not a concern.

Finally, common ownership of land resources, such as parks and streets, is the source of other environmental problems. People who litter in public parks do not generally dump trash on their own property. The lack of enforceable property rights to commonly owned resources explains much of what economist John Kenneth Galbraith has termed "public squalor amid private affluence."

Economic Decision Making and the Biophysical World

For most natural scientists, current crises like biodiversity loss, climate change, and many other environmental problems are symptoms of an imbalance between the socioeconomic system and the natural world. While it is true that humans have always changed the natural world, it is also clear that this imprint is currently much greater than anything experienced in the past. One reason for the profound effect of human activity on the natural world is the fact that there are so many of us.

One of the most serious consequences of the growing human impact on the natural world is the loss of biodiversity. Biological diversity is thought to affect the stability of ecosystems and the ability to cope with crises. In the 570-million-year history of complex life on earth, there have been several major extinction events. The loss of biodiversity after major extinction episodes ranged from 20 percent to more than 90 percent. The loss in biodiversity caused by human activity since the Industrial Revolution alone is somewhere between 10 and 20 percent. If current trends continue, losses are likely to reach 50 percent by the end of the next century. After each extinction event, it took between 20 million and 100 million years for biodiversity to recover to previous levels, a length of time between 100 and 500 times longer than the 200,000-year history of *Homo sapiens.*

The greatest single cause of the loss of biodiversity is habitat destruction, that is, the destruction of the web of organisms and functions that support individual species. The recognition that individual species are supported by others within the ecosystem is foreign to the way markets view the world.

The example of biodiversity illustrates the conflicting frameworks of economics and ecology. Market decisions fail to account for the context of a species or the interconnections between resource quality and ecosystem functions. For example, the value of land used for beef production is measured according to its contribution to output. Yet long before output and the use value of land decreases, the diversity of grass varieties, microorganisms in the soil, or groundwater quality may be affected by intensive beef production. As long as yields are maintained, these changes go unnoticed by markets and are unimportant to land-use decisions.

Another obvious difference between economics and ecology is the relevant time frame in markets and ecosystems. The biophysical world operates in tens of thousands and even millions of years. The time frame for market decisions is short. Particularly where economic policy is concerned, two- to four-year election cycles are the frame of reference; for investors and dividend earners, performance time frames of three months to one year are the rule.

Space or place is another issue. For ecosystems, place is critical. Take groundwater as an example. Soil quality, hydrogeological conditions, regional precipitation rates, plants that live in the region, and losses from evaporation, transpiration, and groundwater flow all contribute to the size and location of groundwater reservoirs. These capacities are not simply transferable from one location to another. For economic activities, place is increasingly irrelevant. Topography, location and function within a bioregion, or local ecological features do not enter into economic calculations except as simple functions of

ENVIRONMENTAL CLOSE-UP

Placing a Value on Ecosystem Services

There are many services provided by functioning ecosystems that are taken for granted. Protection of watersheds by forested land has long been known to be of great value. New York City found that it could provide water to its residents less expensively by protecting the watershed from which the water comes rather than by building expensive water purification plants to clean water from local rivers. Ducks Unlimited, an organization that supports waterfowl hunting, uses money provided by its members to protect nesting habitat for ducks and geese. Many countries have planted trees to help remove carbon dioxide from the air. All of these services can be converted into monetary terms, since it takes money to purify water, purchase land, and purchase and plant trees.

Since choices between competing uses for ecosystems often are determined by financial values assignable to ecosystems, it is important to have some kind of idea about the value of the "free" services provided by functioning ecosystems. Many environmental thinkers have begun to try to put a value on the many services provided by intact, functioning ecosystems. Obviously this is not an easy task and many will belittle these initial attempts to put monetary values on ecosystem services, but it is an important first step in forcing people to consider the importance of ecosystem services when making economic decisions about how ecosystems should be used. The following table represents approximate values for ecosystems services assigned by a panel of experts including ecologists, geographers, and economists. The total of $33 trillion per year is an estimate which many consider to be low. The current world GNP is about $18 trillion per year. Therefore the "free" services of ecosystems must not be overlooked when decisions are made about land use and how natural resources should be managed.

Categories of Services	Examples of Services	Estimated Yearly Value (trillion 1994 U.S. dollars)
Soil formation	Weathering, organic matter	17.1
Recreation	Outdoor recreation, eco-tourism, sport fishing	3.0
Nutrient cycling and waste treatment	Nitrogen, phosphorus, organic matter	2.4
Water services	Irrigation, industry, transportation, watersheds, reservoirs, aquifers	2.3
Climate regulation	Greenhouse gas regulation	1.8
Refuges	Nursery areas for animals, stopping places during migration, overwintering areas	1.4
Disturbance regulation and erosion control	Protection from storms and floods, drought recovery	1.2
Food and raw materials	Hunting and gathering, fishing, lumber, fuel wood, food for animals	0.8
Genetic resources	Medicines, reservoir of genes for domesticated plants and animals	0.8
Atmospheric gas balance	Carbon dioxide, oxygen, ozone, sulfur oxides	0.7
Pollination and pest control	Increased production of fruits	0.5
Total		33*

*Disparity is due to rounding.

Source: Data from R. Costanza, et al. "The Value of the World's Ecosystem Services and Natural Capital," in *Nature* Vol. 387 (1997).

transportation costs or comparative advantage. Production is transferable, and the preferred location is anywhere production costs are the lowest.

Another difference between economics and ecology is that they are measured in different units. The unifying measure of market economics is money. Progress is measured in monetary units that everyone uses and understands to some degree. Biophysical systems are measured in physical units such as calories of energy, CO_2 absorption, centimeters of rainfall, or parts per million of nitrate contamination. Focusing only on the economic value of resources while ignoring biophysical health may mask serious changes in environmental quality or function.

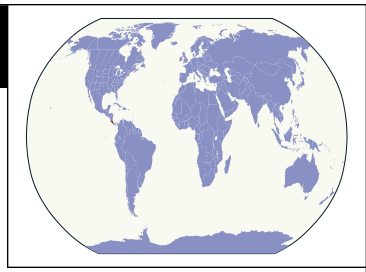
Economics, Environment, and Developing Nations

As previously mentioned, the earth's "natural capital," on which humankind depends for food, security, medicines, and for many industrialized products, is its biological diversity. The majority of this diversity is in the developing world and much of it is threatened by exploitation and development. In order to pay for development projects, many economically poorer nations are forced to borrow money from banks in the developed world.

So great is the burden of external debt that many developing nations see little option but to overexploit their natural resource base. By 2000, the debt in

GLOBAL PERSPECTIVE

Costa Rican Forests Yield Tourists and Medicines



The Central American republic of Costa Rica has been very successful in protecting a significant amount of its remaining forests. It has a rich variety of different kinds of tropical forests and other natural resources. Mangrove swamps, cloud forests, rainforests, dry tropical forests, volcanoes, and beaches on both the Pacific Ocean and the Caribbean Sea are all part of the mix found in an area about the size of West Virginia.

Nearly 20 percent of the land in Costa Rica is protected as parks, reserves, and refuges. This is the result of several factors. The government is committed to preserving natural areas. A major part of the parks program involves educating the local people about the values of the parks, including the biological value of the large number of species of plants and animals and the economic value of the parks as a tourist attraction. The job of educating the people is made easier by the fact that 93 percent of the people are literate.

Many jobs in Costa Rica are in the developing ecotourism market. People who wish to visit natural areas require guides, transportation, food, and lodging. The jobs created in these industries encourage local people to preserve their natural resources because their livelihood depends on it. Furthermore, when people are employed, they are less likely to try to convert forested land into farmland.

In addition to using the natural resources of forests for tourists, the government of Costa Rica has an agreement between its Instituto Nacional de Biodiversidad (INBio) and Merck and Company, Inc. to prospect for possible drugs from many tropical plants and animals found in the forests. In return, Merck will pay $1 million to the Costa Rican government. Specially trained local parataxonomists (technicians trained in the identification of plants and animals) are involved in this search, resulting in additional jobs.

- What conditions have contributed to the apparent success of Costa Rica in protecting its forests?
- What are possible sources of failure in other countries?
- Who benefits from ecotourism?

the developing nations had risen to over US $1,840 billion, a figure almost half their collective gross national product. The debt burdens have led what investment there is in many developing countries to projects with safe, short-term returns and programs absolutely necessary for immediate survival. Environmental impacts are often neglected, the view being that severely indebted countries cannot afford to pay attention to environmental costs until other problems are resolved. This strategy suggests that environmental problems can be "corrected" once a country has reached a higher income level, but it ignores the growing realization that environmental impacts frequently cause international problems. Many countries under pressure from their debt crisis feel forced to overexploit their natural resources, rather than manage them sustainably.

One new method of helping manage a nation's debt crises is referred to as debt-for-nature exchange. Debt-for-nature exchanges are an innovative mechanism for addressing the debt issue while encouraging investment in conservation and sustainable development. The exchanges, or swaps, allow debt to be bought at discount but redeemed at a premium, in local currency, for use in conservation and sustainable development projects. Debt-for-nature originated in 1987, when a nonprofit organization, Conservation International, bought $650,000 of Bolivia's foreign debt in exchange for Bolivia's promise to establish a national park. By 1998, at least 16 debtor countries—in the Caribbean, Africa, Eastern Europe, and Latin America—had made similar deals with official and nongovernmental organizations. By 1998, nearly US $125 million of debt around the world had been purchased at a cost of some US $24 million but redeemed for the equivalent of US $68 million. This money was used to establish biosphere reserves and national parks, develop watershed protection programs, build inventories of endangered species, and develop environmental education.

In debt-for-nature exchanges, debtor countries benefit from the reduction of their foreign-currency debt obligations and add to their expenditure invested at home. The conservation investor receives a premium on the investment. This can be used for conservation and to establish sustainable development projects. Creditor banks gain by converting their nonpaying debts. Although they receive only part of their initial loan, some return is better than a total loss.

The primary goal of debt-for-nature exchanges has not been debt reduction but the funding of natural-resource-management investment. The contribution made by exchanges could increase, as in the case of the Dominican Republic, where 10 percent of the country's outstanding foreign commercial debt is to be redeemed by exchanges. Although eliminating the debt crisis alone is no guarantee of investment in environmentally sound projects, instruments like debt-for-nature exchanges can, on a small scale, reduce the mismanagement of natural resources and encourage sustainable development.

Attitudes of banks in the industrialized nations also seem to be changing. For example, the World Bank, which lends money for Third World development projects, has long been criticized by environmental groups for backing large, ecologically unsound programs, such as a cattle-raising project in Botswana that led to overgrazing. During the past few years, however, the World Bank has been factoring environmental concerns into its programs. One product of this new approach is an environmental action plan for Madagascar. The 20-year plan, which has been drawn up jointly with the World Wildlife Fund,

is aimed at heightening public awareness of environmental issues, setting up and managing protected areas, and encouraging sustainable development.

The Tragedy of the Commons

The problems inherent in common ownership of resources were outlined by biologist Garrett Hardin in a now classic essay entitled "The Tragedy of the Commons" (1968). The original "commons" were areas of pastureland in England that were provided free by the king to anyone who wished to graze cattle.

There are no problems on the commons as long as the number of animals is small in relation to the size of the pasture. From the point of view of each herder, however, the optimal strategy is to enlarge his or her herd as much as possible: If my animals do not eat the grass, someone else's will. Thus, the size of each herd grows, and the density of stock increases until the commons becomes overgrazed. The result is that everyone eventually loses as the animals die of starvation. The tragedy is that, even though the eventual result should be perfectly clear, no one acts to avert disaster. In a democratic society, there are few remedies to keep the size of herds in line.

The ecosphere is one big commons stocked with air, water, and irreplaceable mineral resources—a "people's pasture," but a pasture with very real limits. Each nation attempts to extract as much from the commons as possible while enough remains to sustain the herd. Thus, the United States and other industrial nations consume far more than their share of the total world resource harvest each year, much of it imported from less-developed nations. The nations of the world compete frantically for all the fish that can be taken from the sea before the fisheries are destroyed. Each nation freely uses the commons to dispose of its wastes, ignoring the dangers inherent in overtaxing the waste-absorbing capacity of rivers, oceans, and the atmosphere.

The tragedy of the commons also operates on an individual level. Most people are aware of air pollution, but they continue to drive their automobiles. Many families claim to need a second or third car. It is not that these people are antisocial; most would be willing to drive smaller or fewer cars if everyone else did, and they could get along with only one small car if public transport were adequate. But people frequently get "locked into" harmful situations, waiting for others to take the first step, and many unwittingly contribute to tragedies of the commons. After all, what harm can be done by the birth of one more child, the careless disposal of one more beer can, or the installation of one more air conditioner?

Lightening the Load

Ship captains pay careful attention to a marking on their vessels called the Plimsoll line. If the water level rises above the Plimsoll line, the boat is too heavy and is in danger of sinking. When the line is submerged, rearranging items on the ship will not help much. The problem is the total weight, which has surpassed the carrying capacity of the ship.

This analogy points out that human activity can reach a scale that the earth's natural systems can no longer support. In 1992, more than 1,600 scientists, including 102 Nobel laureates, underscored this point by collectively signing a "Warning to Humanity." Their warning stated in part that "a new ethic is required, a new attitude towards discharging our responsibility for caring for ourselves and for the earth. . . .This ethic must motivate a great movement, convincing reluctant leaders and reluctant governments and reluctant peoples themselves to effect the needed changes."

Such a new successful global effort to lighten humanity's load on the earth would need to directly address three major driving forces of environmental decline: the inequitable distribution of income, resource consumptive economic growth, and rapid population growth. It would redirect technology and trade to buy time for this great change to occur. Although there is much to say about each of these challenges, some key points bear noting.

Wealth inequality may be the most difficult problem, since it has existed for centuries. The difference today, however, is that the future of rich and poor alike depends on reducing poverty and thereby eliminating this driving force of global environmental decline. In this way, self-interest joins ethics as a motive for redistributing wealth, and raises the chances that it might be done.

Important actions to narrow the income gap must include reducing Third World debt. This was talked about a great deal in the 1980s, but little was accomplished. In addition, the developed nations must focus more foreign aid, trade, and international lending policies directly on improving the living standards of the world's poor.

A key description for reducing the kinds of economic growth that harm the environment is the same as that for making technology and trade more sustainable: internalizing environmental costs. If this is done through the adoption of environmental taxes, such as taxing based on pollution emitted, governments could avoid imposing heavier taxes overall by lowering income taxes accordingly. In addition, establishing better measures of economic accounting is critical. Since the calculations used to produce the gross national product do not account for the destruction or depletion of natural resources, this popular economic measure is extremely misleading. It tells us we are making progress even as our ecological foundations are being diminished. A better guide toward a sustainable path is essential. The United Nations and several governments have been working to develop better accounting methods, and while the progress has been slow, there is growing hope in the heightened awareness that a change is necessary.

As our discussion has shown, the economics of environmental problems is complex and difficult. The single most difficult problem to overcome is the assignment of an appropriate economic value to resources that have not previously been examined from an economic perspective. When air, water, scenery, and wildlife are assigned an economic value, they are looked at from an entirely different point of view.

Shrimp, Turtles, and Turtle Excluder Devices

ISSUES & ANALYSIS

The nets used for trawling for shrimp unfortunately do not catch only shrimp. One historic victim of such nets has been turtles, including the endangered Kemp's Ridley sea turtle as well as threatened loggerhead and endangered green sea turtles. Until the mid-1990s, shrimp boats traveling the South Atlantic and Gulf of Mexico could accidentally catch an estimated 45,000 sea turtles in their nets, of which some 12,000 would drown.

The U.S. National Marine Fisheries Service (NMFS), looking for a technological innovation to stop the accidental netting and killing of the turtles, developed a device to keep turtles out of shrimp nets. The turtle excluder device, or TED, attaches to standard shrimp nets. A TED is a grid of bars with an opening either at the top or bottom. The grid is fitted into the neck of a shrimp trawl. Small animals like shrimp slip through the bars and are caught in the bag end of the trawl. Large animals such as turtles and sharks, when caught at the mouth of the trawl, strike the grid bars and are ejected through the opening. Data compiled by the NMFS show that TEDs can reduce turtle captures in shrimp nets by 97 percent with minimal loss of shrimp.

TEDs were first introduced to the shrimp industry on a voluntary basis in 1982. TEDs, however, were not widely accepted and many fishermen claimed that it was not fair for only U.S. fishermen to use them while their counterparts in Mexico did not. The U.S. fishermen argued that they were operating under an unfair economic policy. The shrimpers who opposed the TEDs also claimed that the devices were expensive and dangerous, and cut down on their catches.

TEDs were redesigned with input from the fishermen and there soon followed legislation replacing the voluntary program with a mandated one. The NMFS ensured that the TED requirements were phased in gradually to minimize the impact on the fishery. By 1998, inspectors from the NMFS uncovered only 98 TED violations in 2724 visits aboard shrimp boats.

In 1993, Mexico also mandated the use of TEDs. By the late 1990s, the use of TEDs had spread to many parts of the world. The NMFS and the U.S. Department of State have worked closely with Mexico and the other shrimp-supplying nations in Latin America to help them develop comparable TED programs. TEDs have also been successfully implemented in Thailand, Malaysia, and the Philippines. After actual demonstration and dissemination of results of experiments with TEDs, shrimp fishermen did not resist their use and were understanding of the necessity for using them.

- Can you think of other examples where the development of a new technology has ensured economic growth without endangering one or more species?
- Is it possible to always have a "technological fix"?

Trawling for shrimp also kills several endangered and threatened species of turtles in the South Atlantic and Gulf of Mexico.

Summary

Risk assessment is the use of facts and assumptions to estimate the probability of harm to human health or the environment that may result from exposures to pollutants, toxic agents, or management decisions. While it is difficult to calculate risks, risk assessment is used in risk management, which analyzes factors in decision making. The politics of risk management focus on the adequacy of scientific evidence, which is often open to divergent interpretations. In assessing risk, people frequently overestimate new and unfamiliar risks, while underestimating familiar ones.

To a large degree, environmental problems can be viewed as economic problems. Economic policies and concepts, such as supply/demand and subsidies, play important roles in environmental decision making. Another important economic tool is cost-benefit analysis. Cost-benefit analysis is concerned with whether a policy generates more social benefits than social costs. Criticism of cost-benefit analysis is based on the question of whether everything has an economic value. It has been argued that if economic thinking dominates society, then even noneconomic values, like beauty, can survive only if a monetary value is assigned to them.

A newer school of economic thought is referred to as sustainable development. Sustainable development has been defined as actions that address the needs of the present without

compromising the ability of future generations to meet their own needs. Sustainable development requires choices based on values.

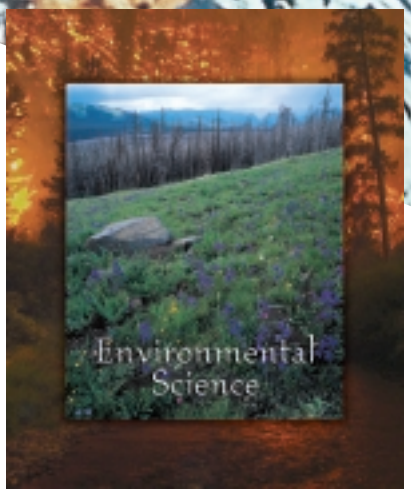
Pollution is extremely costly. When the costs are imposed on society, they are referred to as external costs. Costs of pollution control include pollution-prevention costs and pollution costs. Prevention costs are less costly, especially from a societal perspective.

Economists have stated that when everyone shares ownership of a resource, there is a strong tendency to overexploit and misuse the resource. This concept was developed by Garrett Hardin in "The Tragedy of the Commons."

Recently, a market approach to curbing pollution has been proposed that would assign a value to not polluting, thereby introducing a profit motive to pollution reduction.

Economic concepts are also being applied to the debt-laden developing countries. One such approach is the debt-for-nature swap. This program, which involves transferring loan payments for land that is later turned into parks and wildlife preserves, is gaining popularity.

Interactive Exploration



Check out the website at

http://www.mhhe.com/environmentalscience

and click on the cover of this textbook for interactive versions of the following:

KNOW THE BASICS

carcinogens *41*
cost-benefit analysis *49*
demand *43*
external costs *53*
negligible risk *42*
pollution costs *53*
pollution-prevention costs *53*
probability *39*
resources *43*
risk assessment *39*
risk management *41*
subsidy *46*
supply *43*
supply/demand curve *44*
sustainable development *50*

- On-line Flashcards
- Electronic Glossary

IN THE REAL WORLD

Is your shrimp dinner causing turtle deaths? Is the use of Turtle Exclusion Devices (TEDs) an example of unfair trade restrictions? Although TEDs are used frequently in shrimp trawling and seem to be a technological solution to the problem of drowning sea turtles, all is not solved in the business. Some trawlers are not using the devices, and internationally there are complaints about the use of TEDs. **Gulf Shrimp Trawler Fined for Disabling Turtle Exclusion Device** tells the story of a Louisiana shrimp trawler who is obviously not supportive of TEDs. You can also see how the TED works in the accompanying illustration and explanation.

The World Trade Organization overturned U.S. legislation to ban the import of shrimp from countries that refuse to use TEDs. For more information on how the WTO affects U.S. environmental laws, check out **"Environmental Concerns in the Battle For Seattle," at World Trade Organization Talks.**

Additional information regarding the WTO, economics, and the environment is found in **China Slated to Join the WTO.**

More news on the international scene includes Sweden who leads the way in changing their approach to economic policy by acknowledging the real costs of environmental degradation. Read **Swedish Parliament Plans Budget for Environmental Indicators** to see how this country is attempting to reduce external costs.

Are the conveniences of using plastics and pesticides enough to outweigh the possibility of declining sperm counts and increased breast cancer? Is this just a scare tactic? Investigate these questions with **Endocrine Disrupters on the Gulf Coast,** a case study that discusses the costs and benefits of using pesticides and plastic.

The high demand for plastics and pesticides can lead to potential problems, but there are also problems associated with the high demand for natural products. Is the quest for natural products a modern-day "gold rush" or a Tragedy of the Commons? Check out **Matsutake Mushroom Mania** for the drama that unfolds when there is high demand for a natural product.

TEST PREPARATION

Review Questions

1. How is risk assessment used in environmental decision making?
2. What is incorporated in a cost-benefit analysis? Develop a cost-benefit analysis for a local issue.
3. What are some of the concerns about the use of cost-benefit analysis in environmental decision making?
4. What concerns are associated with sustainable development?
5. What are some examples of environmental external costs?
6. Define what is meant by pollution-prevention costs.
7. Define the problem in common property resource ownership. Provide some examples.
8. Describe the concept of debt-for-nature.

Critical Thinking Questions

1. If you were a regulatory official, what kind of information would you require in order to make a decision about whether a certain chemical was "safe" or not? What level of risk would you deem acceptable for society? For yourself and your family?
2. Why do you suppose some carcinogenic agents, like those in cigarettes, are so difficult to regulate?
3. Imagine you were assessing the risk of a new chemical plant being built along the Mississippi River in Louisiana. Identify some of the risks that you would want to assess. What kinds of data would you need to assess whether the risk was acceptable, or not? Do you think that some risks are harder to quantify than others? Why?
4. Granting polluting industries or countries the right to buy and sell emissions permits is a controversial idea. Some argue that the market is the best way to limit pollution. Others argue that trade in permits allows polluting industries to continue to pollute and concentrates that pollution. What do you think?
5. Imagine you are an independent economist who is conducting a cost-benefit analysis of a hydroelectric project. What might be the costs of this project? The benefits? How would you quantify the costs of the project? The benefits? What kinds of costs and benefits might be hard to quantify, or might be too tangential to the project to figure into the official estimates?
6. Do you think environmentalists should stretch traditional cost-benefit analysis to include how development impacts the environment or shouldn't they? What are the benefits to this? The risks?
7. Looking at your own life, what kinds of risks do you take? What kinds would you be unwilling to take? What criteria do you use to make a decision about acceptable and unacceptable risk?
8. Is current worldwide growth and development sustainable? If there were less growth, what would be the effect on developing countries? How could we achieve a just distribution of resources and still limit growth?
9. Should our policies reflect an interest in preserving resources for future generations? If so, what level of resources should be preserved? What would you be willing to do without in order to save for the future?