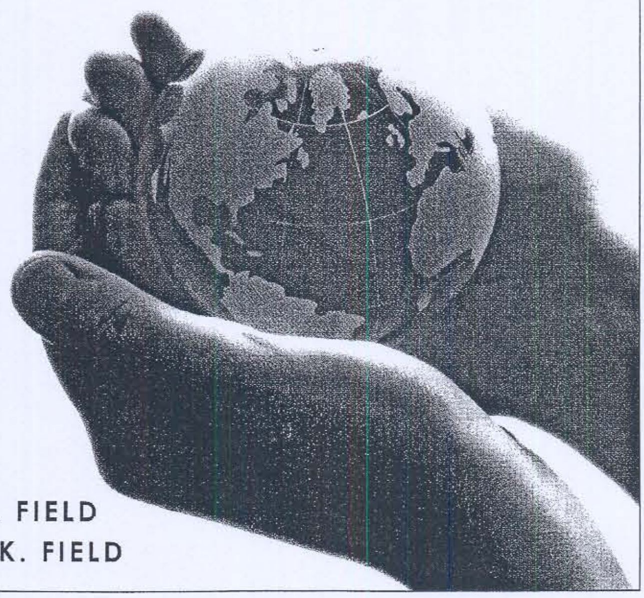
FIFTH EDITION

Environmental Economics

An Introduction



BARRY C. FIELD
MARTHA K. FIELD

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Chapter 1

What Is Environmental Economics?

Economics is the study of how and why individuals and groups make decisions about the use and distribution of valuable human and nonhuman resources. It is not solely the study of profit-making businesses making decisions in a capitalist economy. It is much broader than this; it provides a set of analytical tools that can be used to study any situation in which the scarcity of means requires the balancing of competing objectives. It includes, for example, important questions in the behavior of nonprofit organizations, government agencies, and consumers.

Environmental economics is the application of the principles of economics to the study of how environmental resources are managed. Economics is divided into **microeconomics,** the study of the behavior of individuals and small groups, and **macroeconomics,** the study of the economic performance of economies as a whole. Environmental economics draws from both sides, although more from microeconomics than from macroeconomics. It focuses primarily on how and why people make decisions that have consequences for the natural environment. It is concerned also with how economic institutions and policies can be changed to bring these environmental impacts more into balance with human desires and the needs of the ecosystem itself.

One of our first jobs, therefore, is to become acquainted with some of the basic ideas and analytical tools of microeconomics. To do this at the very beginning, however, would risk giving the impression that the tools are more important than their uses. The tools of analysis are not interesting in themselves but for the understanding they can give us about why the natural environment becomes degraded, what the consequences of this are, and what can be done effectively to reduce this degradation. For this reason, the first chapter is devoted to sketching out, in commonsense terms, the kinds of questions environmental economists ask and the kinds of answers they seek. After a brief discussion of some general issues, we look at a series of examples of some of the problems addressed in environmental economics

Economic Analysis

To study economics is to study the way an economy and its institutions are set up, and how individuals and groups make decisions about transforming and managing scarce resources to increase human wealth, in its broadest sense. Environmental economics focuses on a society's natural and environmental resources, and examines the way people make decisions that lead to environmental destruction and environmental improvements.

Environmental economics is an **analytical subject.** We want not only to describe the state of the environment and changes in it, but also to understand why these conditions exist and how we might bring about improvements in environmental quality. This means we will have to introduce a specialized set of concepts and vocabulary. We also will have to use specialized means of expressing connections between important factors that are involved in the environmental quality issues we explore. To do this economists use what are called **analytical models.** A model is a simplified representation of reality, in the sense that it isolates and focuses on the most important elements of a situation and neglects the others. The models we will use are graphical in nature, and they will be quite simple.[1]

It is important to distinguish between **positive economics** and **normative economics.** Positive economics is the study of what is; normative economics is the study of what ought to be. Positive economics seeks to understand how an economic system actually operates by looking at the way people make decisions in different types of circumstances. A study to show how the housing market reacts to changes in interest rates is an exercise in positive economics. A study to estimate how electric utilities would respond to a new tax on sulfur emissions is also an example of positive economics. However, a study to determine what kind of regulation we ought to adopt for a particular environmental problem is a case of normative economics because it involves more than just knowing how things work; it also involves value judgments. We make use of this distinction repeatedly throughout the book.

The economic approach to environmental issues is to be contrasted with what might be called the **moral approach.** According to the latter, environmental degradation is the result of human behavior that is unethical or immoral. Thus, for example, the reason people pollute is because they lack the moral and ethical strength to refrain from the type of behavior that causes environmental degradation. If this is true, then the way to get people to stop polluting is somehow to increase the general level of environmental morality in the society. In fact, the environmental movement has led a great many people to focus on questions of environmental ethics, exploring the moral dimensions of human impacts on the natural environment. These moral questions are obviously of

[1] The Web page associated with the book contains a section on working with graphs. See

fundamental concern to any civilized society. Certainly one of the main reasons environmental issues have been put on the front burner of social concern is the sense of moral responsibility that has led people to take their concerns into the political arena.

But there are practical difficulties with relying on moral reawakening as the main approach to combatting pollution. People don't necessarily have readily available moral buttons to push, and environmental problems are too important to wait for a long process of moral rebuilding. Nor does a sense of moral outrage, by itself, help us make decisions about all the other social goals that also have ethical dimensions: housing, health care, education, crime, and so on. In a world of competing objectives we have to worry about very practical questions: Are we targeting the right environmental objectives, can we really enforce certain policies, are we getting the most impact for the money, and so on. But the biggest problem with basing our approach to pollution control strictly on the moral argument is the basic assumption that people pollute because they are somehow morally underdeveloped. It is not moral underdevelopment that leads to environmental destruction; rather, it is the way the economic system, within which people make decisions about how to conduct their lives, has been arranged.

The Importance of Incentives

People pollute because it is the cheapest way they have of solving a certain, very practical problem. That problem is the disposal of the waste products remaining after consumers have finished using something, or after business firms have finished producing something. People make these decisions on production, consumption, and disposal within a certain set of economic and social institutions;[2] these institutions structure the **incentives** that lead people to make decisions in one direction rather than another. What needs to be studied is how this incentive process works and, especially, how it may be restructured so that people will be led to make decisions and develop lifestyles that have more benign environmental implications.

One simplistic incentive-type statement that one often hears is that pollution is a result of the **profit motive.** According to this view, in private enterprise economies such as the Western industrialized nations people are rewarded for maximizing profits, the difference between the value of what is produced and the value of what is used up in the production process. Furthermore, the thinking goes, the profits that entrepreneurs try to maximize are strictly monetary profits. In this headlong pursuit of monetary profits, entrepreneurs give no thought to the environmental impacts of their actions because it "does not pay." Thus, in this uncontrolled striving for monetary profits, the only way to reduce environmental pollution is to weaken the strength of the profit motive.

There is substantial truth in this proposition, but also a degree of misunderstanding. It is certainly the case that, if operators of private firms make decisions without taking environmental costs into account, excess pollution will result. But this is true of anybody: private firms, individuals, and public agencies. When individuals pour paint thinner down the sink drain or let their cars get seriously out of tune, they are making decisions without putting adequate weight on environmental consequences. Because individuals don't keep profit-and-loss statements, it can't be profits per se that lead people to pollute. The same can be said of government agencies, which have sometimes been serious polluters even though they are not profit motivated. But the most persuasive argument against the view that the search for profits causes pollution comes from looking at the recent history of Eastern Europe and the former USSR. With the collapse of these ex-Communist regimes, we have become aware of the enormous environmental destruction that has occurred in some of these regions—heavily polluted air and water resources in many areas, which have a major impact on human health and ecological systems. China is currently experiencing the same problem: headlong emphasis on economic development (by both public and private firms) with insufficient regard for the environmental consequences of this process. These examples show that it is not the profit motive itself that causes pollution, but any resource-using and waste-producing decisions that are made without exercising appropriate control over their environmental consequences.

In the sections and chapters that follow, we will place great stress on the importance of incentives in the functioning of an economic system. *Any* system will produce destructive environmental impacts if the incentives within the system are not structured to avoid them. We have to look more deeply into any economic system to understand how its incentive systems work and how they may be changed so that we can have a reasonably progressive economy without disastrous environmental effects.

Incentives: A Household Example

An **incentive** is something that attracts or repels people and leads them to modify their behavior in some way. An "economic incentive" is something in the economic world that leads people to channel their efforts at economic production and consumption in certain directions. We often think of economic incentives as consisting of payoffs in terms of material wealth; people have an incentive to behave in ways that provide them with increased wealth. But there are also nonmaterial incentives that lead people to modify their economic behavior; for example, self-esteem, the desire to preserve a beautiful visual environment, or the desire to set a good example for others.

For a simple first look at the importance of changing incentives to get improvements in environmental quality, consider the story shown in Exhibit 1.1. It

Fort Worth, Texas, Adopts PAYT

EXHIBIT 1.1

When it officially launched its PAYT program on July 1, 2003, the city of Fort Worth was no stranger to PAYT. After conducting an extended, seven-year pilot program, city officials had the basic principles of PAYT down pat. But even that level of familiarity wouldn't prepare them for the success the East Texas city of 502,369 residents would achieve when it introduced the program citywide.

Under the PAYT system and corresponding curbside recycling program—implemented in March 2003—Fort Worth's recycling rate has jumped from 6 percent to 20 percent, and 70 percent of households now recycle, up from just 38 percent. The economic effects are just as encouraging. Under PAYT, 92 percent of residents pay less for garbage disposal than they did under the old system, and the city is saving, too. The cost for municipal solid waste disposal has dropped from almost \$32 million under the old system to approximately \$24 to \$25 million under PAYT, and the city earned \$540,000 from the sale of recycled materials over the course of a year. With a promising first year under its belt, the program continues to expand. The program now serves 163,000 households, and a new route is being added every six weeks.

"Back in 1995, we put together a solid waste management plan," said Brian Boerner, the city's director of environmental management. "It was a public process, with a citizens committee and the whole nine yards, and one of the things they looked at was our landfill capacity in this area and going to a volume-based pay-as-you-throw system—first of all to try to control the volume of waste we're generating, but secondly, to make solid waste the utility that it is, like gas and water and everything else, and actually paying for the volume of waste that you produce."

Fort Worth decided on a cart system with 32-, 64-, and 96-gallon cart options, with monthly fees of \$8, \$13, and \$18, respectively. Residents can purchase a second cart of any size for the standard rate, but citizens who have already purchased two 96-gallon carts may leave additional bags of waste at the curb for no extra fee. All residents receive free recycling services, free yard waste disposal, and can call the city for bulky item pickup.

Combined with increased recycling, Fort Worth's landfill management efforts are paying off. Since March 2003, the city has kept 30,791 tons of recyclables, 11,369 tons of yard trimmings, and 2,618 tons of brush out of landfills. That extension of landfill life will ease taxpayer burden in the long run.

So what is the key to Fort Worth's success? According to Boerner, its education, and Fort Worth didn't skimp when it came to getting the word out to residents about the myriad changes to their garbage service. Prior to implementation, the city cast a wide net with its outreach efforts, using direct mail and local media to teach residents the ins and outs of the new system. City officials also identified community groups and attended their meetings to keep the public informed, and took to the streets as well.

Source: U.S. Environmental Protection Agency, *PAYT Bulletin*, Spring 2004. **www.epa.gov/epaoswer/non-hw/payt/tools/bulletin/spring-04.htm**

their trash collected. This is common practice in most communities. The problem with this approach is that there is simply no incentive for any individual family to limit its trash production, because they will pay the same annual trash-collection fee no matter how much, or little, they produce. This might not be a problem if there were ample landfill space and if there were no danger that the landfill would contaminate the surrounding environment, such as a nearby groundwater system. But for most communities these conditions don't hold any more, if they ever did. Residents of Fort Worth were confronted by rapidly escalating trash-collection costs. They faced the problem of how to get a significant reduction in the quantity of solid waste handled by the city.

The response in this case was to introduce a system that gives people an incentive to search for ways to reduce the amount of solid waste they produce. This was done by charging people for each bag of trash they put on the curb. What this does is to give families the incentive to reduce the number of bags of trash they set out. They can do this by recycling, by switching to products that have less waste, by putting food scraps in a compost pile, and so on. These have led, according to the story, to a large increase in the amount of trash recycled and a reduction in the total amount of trash. There are many other communities around the country where this system has been adopted. Of course, no system is perfect. Increases in illegal dumping and difficulties with applying the plan to apartment houses are problems. Nevertheless, the new approach does illustrate in a very clear way the effects of a shift from a system where there were no incentives for people to reduce their solid waste to one where there are such incentives.[3]

Incentives and Global Warming

Municipal solid waste and other trash have traditionally been local problems, both because the possible environmental impacts are usually local, and because, policy-wise, local governments have had the primary responsibilities for dealing with it. Obviously, not all environmental problems are local: traditional air pollution is usually a regional or national issue, and sometimes it is an international problem because it crosses country borders. And some environmental problems are truly global in that they have causes and impacts that involve everyone around the world, though not necessarily in equal intensity.

Of course, the global issue that is thrusting itself into the world's consciousness is the greenhouse effect, the buildup of heat-trapping gases in the earth's atmosphere that is producing long-run changes in global climate. We will have much more to say about this issue in later chapters. A major focus of environmental economists is to try to identify the most effective

Carbon Trading: The Next Big Thing

EXHIBIT 1.2

In Chapter 13 we will take a close look at emission trading programs: how they work, what they are meant to accomplish, and so on. The idea of using carbon trading to address global warming has become very popular in many countries. A number of European countries are trying to set up a carbon trading system, and many would like to see carbon trading become global in extent. As this happens there will be a major need, and opportunity, for people who know how to participate on carbon trading markets. Many of the big financial trading companies (Merrill Lynch, Goldman Sachs, Morgan Stanley, etc.) have set up carbon trading units. New companies are being formed to specialize in buying and selling carbon emission permits, or to broker transactions deals among others. Trading exchanges are being established. For example, in the U.S., trades can be made on the Chicago Climate Exchange. But the center of carbon trading for now is in London. In that city carbon exchanges are handled by the European Climate Exchange. The monthly quantity of carbon credits traded here has increased rapidly over the last few years. The United Nations is operating an exchange featuring trading between entities in developed and developing countries of the world.

The growing popularity of carbon trading will create a major need for people who understand how carbon markets work, both technically and in relation to the ways that government regulations affect the value of the carbon emission credits. Carbon markets will be a place where the business community, banks, aid organizations, environmental groups, consulting organizations, and others will all participate in essentially a joint effort to create the incentives for the control of greenhouse gases.

policy approaches to combat the emissions of substances causing the greenhouse, especially carbon dioxide (CO_2), but also including many other gases, such as methane (CH_4).

One way to approach this is with conventional "command-and-control" policies. This relies on laws and regulations that directly or indirectly specify pollution-control technologies or practices that polluters should use. Then standard enforcement procedures are used (inspections, monitoring, fines, etc.) to produce acceptably high degrees of compliance. While this approach still characterizes much of the environmental policy arena, there has been a lot of attention recently given to incentive-based policies. One type of **incentive-based policy** is to charge firms for the pollution-causing material they emit into the environment. A charge of so much per pound, or per ton, would be put on the emissions, and the firms would be sent a bill at the end of each month or year, based on the total quantity of their emissions during that period. With environmental emissions now costly, firms would have the incentive to search for ways of reducing their emissions, perhaps by changing

In recent years the most popular **incentive-based** approach has become what is called **cap-and-trade** policies. Individual sources of pollutants are issued emission permits, which may be bought and sold in transactions with other sources, or with other market permits. A cap on the total number of permits ensures that total air or water pollution will be reduced. The chance to buy and sell permits gives firms an incentive to search for the most cost-effective means of reducing their emissions. We will study cap-and-trade programs in Chapter 13.

Incentive-based environmental policies work by facing polluters with the full social costs of their actions, and offering them some flexibility in how they go about reducing their emissions. There is another important role for incentives: to stimulate the envirotech sector of the economy to produce and make available new and more effective pollution-control technology and services. Exhibit 1.2 discusses an example of this, the growing opportunities for employment in public and private organizations that are involved in emission permit trading markets.

The Design of Environmental Policy

Environmental economics has a major role to play in the design of **public policies** for environmental quality improvement. There are an enormous range and variety of public programs and policies devoted to environmental matters, at all levels of government: local, state, regional, federal, and international. They vary greatly in their efficiency and effectiveness. Some have been well designed and will no doubt have beneficial impacts. Others are not well designed. Not being cost-effective, they will end up achieving much less environmental improvement than they would have if they had been designed better.

The problem of designing efficient environmental policies is often not given the emphasis it deserves. It is easy to fall into the trap of thinking that any programs or policies that flow out of the rough and tumble of the environmental political process are likely to be of some help, or that they certainly will be better than nothing. But history is full of cases where policymakers and public administrators have pursued policies that don't work; the public is frequently led to believe a policy will be effective even when any reasonable analysis could predict that it will not. All of which means that it is critically important to study how to design environmental policies that are effective and efficient.

In 1994 pollution control costs in the United States amounted to about 1.6 percent of GDP, which figures out at about $113 billion. The EPA expected this percentage gradually to increase over the next few decades.[4] These are very large amounts of money, even though we could probably agree that they ought to be higher. A question of great importance, however, is whether we are getting the most improvement possible in environmental quality for the money spent. Former EPA Director William Reilly is quoted as saying that "at this level of expenditure, there's a very large obligation to get it right." By "getting it right" he means having programs that get the maximum improvement in environmental quality for the resources spent. Everybody has an interest in this: environmentalists, for obvious reasons; public regulators, because they are tapping a limited supply of taxpayer resources and consumer tolerance; and the regulated polluters themselves, because matters of efficiency are critical to business success.

"Getting it right" means paying attention to the factors that affect the cost-effectiveness of environmental regulations, and especially to the way they create incentives for actions taken by polluters. A major problem in environmental policy is that of **perverse incentives;** that is, incentives created by a policy that actually work against the overall objectives of that policy. Environmental policies have been notoriously subject to perverse incentives, because environmental policymakers have too often tried to legislate results directly, rather than establish the types of regulations that cause people to alter their behavior in desirable ways. Exhibit 1.3 discusses perverse incentives in the federal program to encourage higher-mileage cars. Although this was undertaken as an energy-conservation measure, it obviously has major implications for the amount of mobile-source air pollution in the United States.

Issues related to the design of environmental policy are a major part of environmental economics. It is important to know how alternative policy approaches measure up in terms of cost effectiveness, getting the most pollution reduction for the money spent, and, in terms of efficiency, appropriately balancing the benefits and costs of environmental improvements.

Macroeconomic Questions: Environment and Growth

The incentive issues discussed in the previous section are microeconomic problems; they deal with the behavior of individuals or small groups of consumers, polluting firms, and firms in the pollution-control industry. The macroeconomy, on the other hand, refers to the economic structure and performance of an entire country taken as a single unit. When we study topics such as changes in gross domestic product (GDP), rates of inflation, and the unemployment rate, we are focusing on the performance of the country as a whole; that is to say, we are doing macroeconomics.

There are a number of important questions about the relationship between environmental issues and the behavior of the macroeconomy. One is the rela-

Perverse Incentives from Public Regulation — EXHIBIT 1.3

Mobile-source pollution results not only from the decisions made by the vehicle-making companies, but also from the millions of decisions made by individuals who buy and use the vehicles. In this complex situation, regulations aimed at one objective can have unexpected, and sometimes perverse, consequences. In the 1970s Congress enacted the CAFE requirements. CAFE stands for corporate average fuel economy. This was a requirement that auto makers produce cars which, on average, achieved certain minimum mileage (miles per gallon) in performance. The objective was gradually to evolve the U.S. auto fleet toward higher levels of energy efficiency (these were the days of the so-called energy crisis). Since emissions of pollutants from cars are to a large extent related to the amount of fuel they burn, CAFE was also expected to yield benefits in terms of reduced air pollution.

But in several ways the CAFE program had the effect of weakening the country's efforts to reduce mobile-source air pollution. Under the program the companies produced higher-mileage cars. But for a given gas price, higher mileage means lower costs per mile. When drivers face lower costs per mile, they do the obvious thing: they drive more miles. Thus, part of the hoped-for savings in fuel consumption (estimates are about 10 to 30 percent) are lost due to the increased number of miles that the CAFE cars have been driven.

The fleet composition effect has been much more damaging. CAFE standards have been less stringent for trucks than for cars; the thought at the time was that vehicles used for commercial purposes should be allowed to meet lower standards. But auto companies responded by shifting their output. Rather than continue to produce large numbers of higher-mileage cars that consumers were not particularly interested in, they introduced new vehicles that counted as trucks under CAFE, but were increasingly used as personal vehicles by consumers. Trucks—SUVs, minivans, and pickups—now account for almost two-thirds of the personal vehicle fleet. The paradoxical effect of this is that the light-duty vehicle fleet, meaning vehicles people use largely for personal use, gets on average worse mileage now than

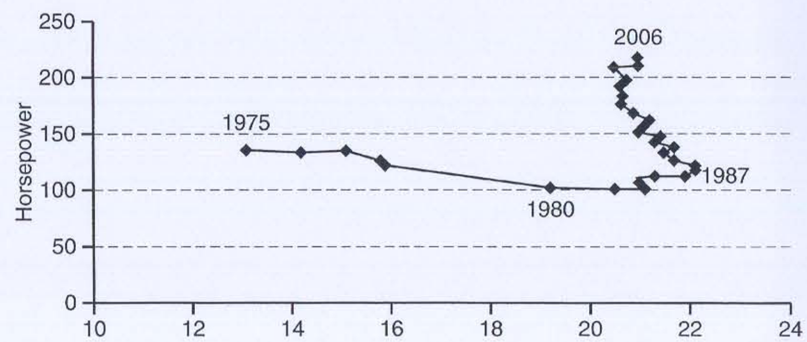


EXHIBIT 1.3 *(Continued)*

it did 20 years ago. This can be seen in the accompanying figure, which shows the fuel economy (miles per gallon) of light-duty vehicles in the U.S. from 1975 to 2006.

This is a good example of how policy-makers, seemingly making decisions to ameliorate real problems, can actually make them worse. It also shows how everything is intertwined; decisions in one part of the system can affect performance and results elsewhere. This is not an argument for doing nothing, but it is an argument for thinking through the plans that are adopted.

Source: U.S. EPA, *Light-Duty Automotive Technology and Fuel Economy Trends: 1975–2006*, Washington, DC, 2006 **(www.epa.gov/otaq/fetrends.htm).**

and increase unemployment and, if so, how much? There are some who feel that overly strict environmental regulations will have a retarding effect on economic growth. This is seemingly the source of much of the opposition to stricter controls on greenhouse gas emissions. Undoubtedly there have been instances where environmental regulations have been blamed for creating an economic burden: the impact on the timber industry of spotted-owl protection, for example. But there is little evidence that from the perspective of the total economy, environmental protection costs have been a significant economic burden. As mentioned above, pollution-control costs today are probably about 2 percent of GDP in the country. Costs of this magnitude are simply not large enough to cause large-scale layoffs and reduced economic growth.[5] Nevertheless, this question continues to be politically sensitive. Exhibit 1.4 discusses this issue in specific relation to the effort to reduce atmospheric emissions that are causing global warming.

Another macroeconomic question concerns the impacts of economic growth on environmental quality. Do higher rates of growth, that is, increases in our traditional measures such as GDP, imply greater environmental degradation or might the opposite be true? Two economists who studied this problem recently concluded: "some pollution increases during the early stages of a country's development and then begins to diminish as countries gain adequate resources to tackle pollution problems."[6] This happens because at low incomes people tend to value development over environmental quality, but as they achieve greater wealth they are willing to devote greater resources to environmental quality improvements. This is clearly a matter of great importance for developing countries, and we come back to it in

[5] On this see Frank Arnold, "Environmental Protection: Is It Bad for the Economy? A Nontechnical Summary of the Literature," U.S. Environmental Protection Agency, 1999. At **http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/EEBasics.html**

The Macroeconomic Cost of CO_2 Emission Reductions

EXHIBIT 1.4

Global warming is the process by which the buildup of certain gases in the earth's atmosphere increases its heat-trapping capacity sufficiently to produce an increase in mean global surface temperatures. A small increase in this could have major meteorological repercussions, with huge economic and social impacts around the world. Scientists have almost unanimously concluded that the only way of effectively forestalling global warming in the long run is to reduce the emissions of greenhouse gases, chief among which is carbon dioxide (CO_2). Emissions of CO_2 stem largely from the burning of fossil fuels, which is ubiquitous in the industrial, transportation, and domestic sectors of modern economies. But how much to try to reduce these emissions is highly controversial. Many in the environmental community believe that vigorous action is required. The current (2005) administration in Washington has taken the position that cutting CO_2 emissions very much would be too costly for the U.S. economy. But how much would it cost?

One way to try and answer this question is to conduct macroeconomic analyses of the U.S. economy, linking past energy consumption with historical levels of economic activity through statistical analysis. There are many factors that would affect the results. How we try to reduce emissions is one important one; if it's done through the use of programs that are cost-effective (i.e., they achieve the greatest emission reduction for the money spent) the overall cost will be lower than if programs are not so designed. If we get rapid future improvements in energy conversion technologies (e.g., solar energy), we can expect to have lower overall emission control costs.

One report put out by the Intergovernmental Panel on Climate Change (IPCC) estimates that limiting U.S. carbon emissions to roughly their 1990 level (the Kyoto Protocol, which we will look at in Chapter 20, calls for reducing emissions to 95 percent of this level) would cost the U.S. economy somewhere between 0.4 and 2.2 percent of U.S. gross national product.[1] On an aggregate basis this would seem like a lot, though on an individual basis it would represent a relatively modest change. But the cost increase would not necessarily strike everybody equally, which is one of the reasons such estimates can be so controversial. Many other macroeconomic studies of CO_2 emission reduction costs have been done, and gradually we will get a better feel for what the full economic implication will be of coming to grips with the problem of global warming.

[1] Intergovernmental Panel on Climate Change, Working Group III, *Climate Change 1995: Economic and Social Dimensions of Climate Change*, ed. James P. Bruce, Hoesung Lee, and Erik F. Haites, Cambridge University Press, New York, 1996.

Chapter 19. Exhibit 1.5 discusses their particular problem in China. In developed countries also, macroeconomic problems—growth, recession, inflation, unemployment—are constant topics of national concern. So it's important to

Economic Growth and Environmental Problems in China — EXHIBIT 1.5

China is experiencing a period of intense economic growth unlike anything the world has ever seen. The story of this growth is familiar to almost everyone. Vice Premier Wu Bangguo recently summarized this story as follows: "Over the past 20 years, under the guidance of Deng Xiaoping theory, China has practiced reform and opening up, successfully opening up a road of building socialism with Chinese characteristics. China's social productive forces have developed rapidly, its overall national strength has grown notably, and its livelihood has continued to improve."

Since the start of reforms, China's economy has surged, growing at an average rate of 10 percent a year. Some coastal areas have grown at nearly 20 percent a year. In that period, China's GDP, in real terms, increased nearly five times. China's push toward a market economy (albeit with "Chinese characteristics") has made China one of the five fastest growing economies in the world. In the process, some 125 million people have been lifted from "absolute poverty" since the beginning of reforms. The growing prosperity has improved quality of life in multifaceted ways—reducing infant mortality, improving child and maternal health, and lengthening life expectancy, for example.

This is the good news about China's growth and development across the past three decades.

The problem is that China's impressive growth has come at the cost of equally spectacular environmental degradation. Since the beginning of reforms, the most commonly measured forms of environmental pollution—particulate matter concentrations, sulfur dioxide levels, greenhouse gas emissions—have all increased literally to life-threatening levels.

For example:

- Eight of the ten most polluted cities in the world are now located in China.
- In 1995, ambient concentrations of sulfur dioxide (SO_2) in over half of 88 Chinese cities monitored exceeded World Health Organization (WHO) guidelines for safety.
- 85 of 87 cities exceeded WHO guidelines for total suspended particulate matter (TSPs); in many cities the concentrations were two to five times safety levels given by WHO guidelines.
- The percentage of arable land affected by acid rain increased from 18 percent to 40 percent between 1985 and 1998.
- China now releases 13 percent of global carbon dioxide (CO_2) emissions. This is second to only the United States (23 percent). With the increase in auto usage in China and development in general, this number is increasing rapidly. China will soon attain the top position if growth trends continue.

Moreover, the aforementioned problems all fall within the realm of air pollution. This discussion does not even touch on the issues of water pollution, loss of rare and endangered species, deforestation, desertification, or soil erosion; these problems and others, though not discussed in this article, are no less serious.

The social and economic costs of this environmental pollution are quite high. The World Bank estimates that air and water pollution cost China US$54 billion per year, or about eight percent of GDP. The World Bank further estimates that, every year, just the air pollution in excess of China's own air quality standards results in 6.8 million emergency room

EXHIBIT 1.5 ***(Continued)***

visits, 346,000 hospital admissions, and 178,000 premature deaths. In addition, air pollution causes some 7.4 million work-years to be lost annually. The numbers here are so uniformly large that they become a bit numbing; the numbers are too abstract in their largeness. Anyone who has ever been to China can attest to the very tangible ways in which environmental pollution reduces quality of life—the dank atmospheric haze, the way the air hurts the lungs and eyes, the way white shirts turn brown after a day outside.

Pollution has other economic costs as well. For example, sulfur dioxide emissions have created acid rain, with damaging effects on agriculture, forest ecosystems, as well as human health. The World Bank estimates that acid rain causes crop and forest losses of $5 billion a year. Of international concern is China's contribution to global warming. At current rates of increase, global atmospheric concentrations of carbon dioxide could double by 2050. China's rising emissions of greenhouse gases is a major contributor to this global growth rate.

Source: Excerpted from "The Downside of Growth: Law, Policy and China's Environmental Crisis," by Alex Wang, *Perspectives*, Vol. 2, No. 2, October 31, 2000.

Benefit–Cost Analysis

Effective decision making requires that there be adequate information about the **consequences** of the decisions. This is as important in the **public sector,** where the issue is effective **public policy,** as it is in the **private sector,** where the main concern is with the bottom line of the profit and loss statement. The primary type of public sector analysis in environmental policy questions is **benefit–cost analysis.** Policies or projects are studied in terms of the environmental benefits they would produce, and these are compared with the costs that are entailed. It was first used in this country early in the 20th century to evaluate water development projects undertaken by federal agencies.[7] Today it is used by many government agencies to help make rational policy decisions.

Benefit–cost analysis is such an important and widely used approach that we devote several chapters to it later in the book (Chapters 6, 7, and 8). In this type of analysis, as the name implies, the benefits of some proposed action are estimated and compared with the total costs that society would bear if that action were undertaken. If it is a proposal for a public park, for example, the benefits in terms of recreational experiences provided by the park are compared with the expected costs of building the park and of using the land in this way rather than some other way. Or a proposal to build a solid-waste incinerator would compare the costs of building and operating the incinerator, including

[7] These were the U.S. Army Corps of Engineers in the Defense Department, the Bureau of Reclamation in the Department of Interior, and the Soil Conservation Service (now called the Natural Resource Conservation Service) in the Department of Agriculture.

Benefits and Costs of Reducing Nitrogen Oxide (NO_x) Emissions — EXHIBIT 1.6

Nitrogen oxide (NO_x) emissions are produced from a variety of industrial and transportation sectors, as a consequence of the burning of fossil fuels. NO_x reacts with volatile organic compounds in the presence of sunlight and produces ground-level ozone, ambient concentrations of which produce a range of health damages. NO_x emissions are also precursors of particulate matter (PM), which is fine soot or dust that can be composed of a number of substances and have deleterious effects on human health. Thus, reducing NO_x emissions has been a major objective of the EPA and many state environmental agencies. To support these efforts a number of economic studies have been done to estimate the benefits and the costs of reducing NO_x emissions. To do this, researchers examine the various types and location of sources of NO_x emissions (e.g., power plants, industrial boilers) and what it would cost these sources to reduce these emissions by a given amount. On the other side, they must estimate the effect of these reductions on ambient ozone levels, and the benefits of these reductions for people living and working in these ambient conditions.

Recently a group of economists conducted a benefit–cost analysis of NO_x emission reductions in 19 eastern U.S. states and regions.[1] They asked the question: What would be the benefits and costs of a 20 percent reduction in NO_x emissions from 925 large electric utility boilers in these states? To estimate the costs they looked at the different technical options available to reduce emissions and identified the least costly alternative for meeting the emission reductions. To estimate the benefits they used a model showing the relationship between emission reductions and changes in ambient ozone and PM, and another model to estimate the health effects of these ambient changes.

Some of these results are as follows:

NO_x reduction (tons/day)	987
Costs ($1,000/day)	$914
Benefits ($1,000/day):	
Ozone reduction	$238
PM reduction	$1,541
Total benefits	$1,779
Net benefits ($1,000/day)	$864

Note that the health benefits of PM reduction are about six times higher than those of the ozone reduction. Note also that there are substantial net benefits (total benefits minus total costs). These amount to $864,000 per day, which translates into about $315 million per year. Results of benefit–cost analyses of this type can help buttress the case for tightening air pollution control standards under the Clean Air Act.

[1] Michelle S. Bergin, Jhih-Shyang Shih, Alan J. Krupnick, James W. Boylan, James G. Wilkinson, M. Talat Odman, and Armistead G. Russell. "Regional Air Quality: Local and Interstate Impacts of NO_x and SO_2 Emissions on Ozone and Fine Particulate Matter in the Eastern United States." Environmental Science and Technology, Vol. 41, No. 13, 2007.

the costs of disposing of the remaining ash and the costs of possible airborne emissions, with benefits, such as reducing the use of landfills for the solid waste. Exhibit 1.6 shows some results of a recent study to estimate the benefits and costs of reducing nitrogen oxide (NO_x) emissions in a group of eastern U.S. states.

The benefit–cost approach implies that we need to consider both the benefits and the costs of environmental programs and policies. This often puts benefit–cost studies squarely in the middle of political controversy on many environmental issues. In the political struggles that characterize many environmental problems, groups on one side consist of people whose major concern is with the benefits, whereas groups on the other side are primarily concerned with costs. Environmental groups typically stress the benefits; business groups usually focus on the costs.

Valuing the Environment

To complete a benefit–cost analysis of an environmental program or regulation successfully, it's necessary to estimate both the benefits and the costs of the actions. One factor that complicates this type of analysis is that the benefits of environmental improvements are usually **nonmarket** in nature. If we were trying to assess the benefits to society of a program to support potato farmers, we could get a good idea of the value of potatoes by looking at how much people are willing to pay for them when they buy them at the supermarket. But suppose we have a program of air pollution reduction that will, among other things, lower the risk that people in a certain region will have of contracting chronic bronchitis. How might we estimate the social value of this result? It cannot be done by looking directly at market behavior, as in the case of potatoes, because there is no market where people buy and sell directly the changes in health risk produced by the environmental program. Environmental economists have developed a series of **nonmarket valuation techniques** that are used to estimate these types of environmental outcomes. We will discuss some of these techniques in Chapter 7.

Suburban Sprawl

One of the most important changes over the last century that has affected the lives of virtually everybody is the **suburbanization** of society. Essentially this means the spreading out of urban areas and lower-density living for a substantial fraction (not all) of the population. It is usually referred to as urban sprawl. Sprawl is normally used in a negative sense, as something that is undesirable. The visual manifestation of sprawl is the proliferation of relatively low-density suburban developments on the fringe; "leapfrogging," in which new development leaves a temporary gap that gets filled in over time; and "edge cities," which are secondary centers of high density commercial development some distance from the center of a large, parent, urban district.

Sprawl is clearly a land-use, quality-of-life problem. Sprawl uses up large amounts of fringe area, with lost agricultural and ecological benefits. It has produced a massive growth in road congestion and the lost time this implies. Sprawl has important visual impacts. It also has important environmental effects. Urban air pollution is closely related to the tremendous amount of automobile commuting that goes with sprawl.

Road Pricing: What's the Deal?

EXHIBIT 1.7

Anthony Ockwell

Ever been late for work and blamed the traffic? The likelihood is (assuming the excuse is true) that you were in fact causing the traffic, too. After all, your car forms part of a line and is holding up the car behind. So by definition, we do not just get stuck in traffic, we produce it.

Traffic congestion comes in all shapes and sizes, usually in towns and cities, but not always: the longest traffic jam ever recorded occurred not in New York or Tokyo or Mexico City, but on the French motorway between Lyon and Paris on 16 February 1980. It tailed back for 176 km (109 miles).

Congestion is inefficient, polluting, and dangerous. So why not reduce it? Removing just 5% of traffic at peak times could substantially reduce or even eliminate rush hour congestion from many cities. One approach that is beginning to stoke interest among municipal leaders, even in large metropolitan capitals like Paris and London, is road pricing. The theory seems sound enough: introduce a price on bringing cars into congested areas that incites drivers either not to travel unnecessarily or to vary their times of travel or, indeed, to try public transport, walking, or cycling. With the right approach, drivers who incur higher prices during rush hour periods would benefit from reduced congestion and travel time, while nonessential travel would take place at less congested and cheaper times. . . .

Road pricing has been debated in policy circles for many years. In bygone days, technology was a problem: how do you tag cars? Do you set up road rolls? These problems no longer exist, and advances in electronic devices have made sophisticated road pricing schemes more feasible. . . . Several pilot schemes for urban transport pricing are under way in the OECD area, in places like Bristol and Cambridge (UK), Orange County, California (US), Copenhagen (Denmark), Edinburgh (UK), Genoa (Italy), Gothenburg (Sweden), Helsinki (Finland), Rome (Italy), and Trondheim (Norway). . . .

To be successful, road pricing would have to have several basic elements. First, prices should be allowed to vary according to the level of demand—as traffic volume increases, price increases. And when congestion falls, so should the price, even to zero when possible, as that would maintain public support. In particular, road prices should not be allowed to become "just another municipal tax."

Second, a balance between affordability and congestion objectives is important; some people (and not always high earners) have to travel at peak times and may require help from their employers who will benefit anyway from less congestion.

Third, revenues should be spent on improving public transport, parking facilities, cycle lanes, etc.

Of course, road pricing alone will not solve every urban environmental problem and should be viewed as part of a broad suite of measures designed to achieve a sustainable transport system. Research and development on solutions to reduce transport emissions, like developing clean technology, would be part of that suite, as might other innovations, such as a greater effort to achieve more flexible work times. . . .

Source: *OECD Observer*, March 2002.

From the standpoint of economics, sprawl has many dimensions. There are essentially two tasks: to understand the factors that lead to inefficient levels of sprawl and then to come up with efficient and equitable policy prescriptions for changing it if that is what is called for. A major element in producing sprawl is the cost of transportation. The lower the costs of transport, other things being equal, the more feasible it is for people to live farther away from their workplaces and commute. An important factor affecting travel costs is the way roads are managed. In effect many of them are treated as free goods; road access is open to anybody at any time. A scarce item, road capacity, is being used at zero price. There have been a few experiments around the world with charging drivers' congestion prices, but the idea is catching on only slowly in most places. Exhibit 1.7 discusses the issue of pricing road access.

International Issues

Many environmental problems are local or regional, in the sense that the causal factors and resulting damages lie within the same country. But many others are international in scope. Some are **international** simply because there is a national border between the pollution source and the resulting impacts. Airborne emissions that are carried from one country upwind to another downwind are a case in point, as is water pollution of a river that traverses several countries. There is another class of problems that are **global** in nature because they impact the global environment. One of these is the destruction of the earth's protective layer of **stratospheric ozone** by chemicals devised by humans for a number of industrial purposes. Another is the problem of **global warming,** the possible rise in surface temperatures of the earth stemming from the accumulation of carbon dioxide in the atmosphere. The 1997 Kyoto conference featured an attempt by developed countries to agree on future cutbacks of CO_2 emissions. Cost-effective CO_2 emission reductions and the design of equitable international agreements are two topics among many on which environmental economists have worked.

The Kyoto Protocol is set to expire in 2012, and there is hope that the countries of the world will negotiate a new and better agreement to reduce emissions of greenhouse gases. How this plays out will depend on the negotiating skills of the parties, and on the incentives that the countries have to take part in an effective agreement. What complicates this is the fact that different countries are likely to be differently affected by global warming, so they come to the bargaining table with different incentives for entering into a meaningful agreement.

To get an idea of the magnitude of this situation, Table 1.1 shows some data for 2004 CO_2 emissions, per capita, for a small group of countries. Note the enormous differences, from 10.13 tons in Kuwait to nothing in Chad. Even among countries of the "developed" world there is great variation, e.g., 5.61 tons in the United States and 1.64 tons in France. A topic of increasing interest is how differences such as this affect the willingness of countries to enter into international

TABLE 1.1 Per Capita CO_2 Emissions for Selected Countries, 2004

Country	CO_2 Emissions per Capita, 2004 (metric tons)
Kuwait	10.13
U.S.	5.61
Australia	4.41
Russia	2.89
United Kingdom	2.67
Poland	2.19
France	1.64
Portugal	1.53
Mexico	1.14
Iraq	.82
Panama	.49
Bolivia	.21
Sudan	.08
Nepal	.03
Chad	.00

Source: Gregg Marland, Tom Boden, and Bob Andres, Oak Ridge National Laboratory (**http://cdiac.esd.ornl.gov/trends/emis/top2004.cap**).

environmental agreements, and how the terms of these agreements might be shaped so as to motivate widespread participation. We will take up these matters in Chapter 21.

Globalization and the Environment

There is another sense in which global environmental problems have recently taken on greater urgency. These are the environmental implications of globalization. **Globalization** is a term used to refer to the perceived changes that are taking place in the world economy, including the rapid growth of **trade** among nations, **privatization** of economic institutions, massive international flows of **financial capital,** and growth in the numbers and sizes of **multinational firms.** Advocates of a more integrated world economy point to its potential for stimulating economic growth and increasing wealth in the developing world. But many people also have pointed to the potential downside of globalization, one part of which may be the degradation of natural environments in developing countries.

Globalization has become a politically charged concept; it is sometimes hard to cut through the rhetoric and identify the substantive issues that are involved. One part of globalization is the substantial increase that has occurred in the volume of trade among nations. This has led to a concern about the implications of the increasing volume of trade on environmental impacts in both developed and developing countries. International trade in goods and services has been

touted as an engine of growth for the countries involved. Some people take the view that the long-run environmental implications of this are positive. Many others feel that unrestricted trade will have severe environmental consequences. We will take up this topic at greater length in Chapter 21.

Another aspect of globalization is the growth of multinational firms and the relocation of industrial firms from developed to developing countries. Environmental regulations are often less stringent in the latter than in the former. The fear is that some developing countries could become **pollution havens,** places to which firms move in order to have to spend less on pollution control measures. We will look more closely at this phenomenon in Chapter 20.

Economics and Politics

Finally, we need to discuss briefly the question of how to achieve effective environmental policy in a highly **political policy environment.** Environmental policies not only affect the natural environment, but also affect people. This means that environmental policy decisions come out of the political process, a process where, at least in democratic systems, people and groups come together and contend for influence and control, where interests collide, coalitions shift, and biases intrude. Policies that come out of a process like this may bear little relationship to what we might think of as efficient approaches to particular environmental problems. Many people have questioned the very idea that a democratic political process could or should strive to produce policies that are efficient in some technical economic sense.

So where does that leave the environmental economist? Why spend so much time and energy on questions of efficiency and cost-effectiveness when the political process most likely is going to override these considerations and go its own way? Why worry about economic incentives and economic efficiency when "everything is political," as the saying goes? The answer is that although we know that the real world is one of compromise and power, the best way for scientists and economists to serve that process is to produce studies that are as clear and as objective as possible. It is the politician's job to compromise or seek advantage; it is the scientist's job to provide the best information he or she can. For economists, in fact, this means studies in which economic efficiency is a central role, but it means more than this. Because the policy process is one where "who gets what" is a dominant theme, environmental economics also must deal with the distribution question, on how environmental problems and policies affect different groups within society. It is also the role of scientists and economists to provide information to policymakers on alternative courses of action. Although we will focus in later chapters on what appear to be "the" most efficient policies or "the" least-cost courses of action, it has to be recognized that in the give-and-take of the political world in which policy is actually made, choosing among alternatives is always the order of the day.

But economists have no right these days to complain about their role in the environmental policy process. If anything these are the days of the rising influence of economists. Benefit–cost procedures and results have become more widely accepted, in public policy arenas and in law courts hearing environmental cases. New pollution-control initiatives incorporating economic incentive principles are being adopted at both federal and state levels in the United States. All the more reason, then, to study and understand the basic economics of environmental analysis and policy.

Summary

The purpose of this brief chapter was to whet your appetite for the subject of environmental economics by indicating some of the main topics that the field encompasses, showing very briefly the approach that economists take in studying them. It's also to give you something to remember. When we get involved in some of the conceptual and theoretical issues that underlie the topic, it is easy to lose sight of what we are trying to accomplish. We are trying to develop these principles so that we can actually use them to address real-world problems such as those discussed in this chapter. Although the principles may appear abstract and odd at first, remember the objective: to achieve a cleaner, healthier, and more beautiful natural environment.

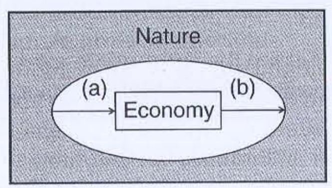
For additional readings and Web sites pertaining to material in this chapter see **www.mhhe.com/field5e**.

Chapter 2

The Economy and the Environment

The **economy** is a collection of technological, legal, and social arrangements through which individuals in society seek to increase their material and spiritual well-being. The two elementary economic functions pursued by society are **production** and **distribution.** Production refers to all those activities that determine the quantities of goods and services that are produced and the technological and managerial means by which this production is carried out. **Distribution** refers to the way in which goods and services are divided up, or distributed, among the individuals and groups that make up society. Distribution puts goods and services in the hands of individuals, households, and organizations; the final utilization of these goods and services is termed **consumption.**

Any economic system exists within, and is encompassed by, the natural world. Its processes and changes are of course governed by the **laws of nature.** In addition, economies make use directly of natural assets of all types. One role the natural world plays is that of provider of raw materials and energy inputs, without which production and consumption would be impossible. Thus, one type of impact that an economic system has on nature is by drawing upon raw materials to keep the system functioning. Production and consumption activities also produce leftover waste products, called "residuals," and sooner or later these must find their way back into the natural world. Depending on how they are handled, these residuals may lead to pollution or the degradation of the natural environment. We can illustrate these fundamental relationships with a simple schematic:



The link marked (a) represents raw materials flowing into production and consumption. The study of nature in its role as provider of raw materials is called **natural resource economics.** The link labeled (b) shows the impact of economic activity on the quality of the natural environment. The study of this residuals flow and its resultant impacts in the natural world comes under the heading of **environmental economics.** Although pollution control is the major topic within environmental economics, it is not the only one. Human beings have an impact on the environment in many ways that are not related to pollution in the traditional sense. Habitat disruption from housing developments and scenic degradation from any number of human activities are examples of environmental impacts that are not related to the discharge of specific pollutants.

The topic of this book is environmental economics. We will study the management of waste flows and the impacts of human activity on the quality of environmental assets. But in a real sense many of these problems originate in the earlier, raw material phase of the nature–economy interaction. So before proceeding, we consider briefly the major dimensions of natural resource economics.

Natural Resource Economics

In modern industrial/urban societies it is sometimes easy to overlook the fact that a large part of total economic activity still relies on the extraction and utilization of natural resources. **Natural resource economics** is the application of economic principles to the study of these activities. To get a general impression of what this discipline includes, the following is a list of its major subdivisions and examples of questions pursued in each one.[1]

Mineral economics: What is the appropriate rate at which to extract ore from a mine? How do exploration and the addition to reserves respond to mineral prices?

Forest economics: What is the appropriate rate to harvest timber? How do government policies affect the harvest rates pursued by timber companies?

Marine economics: What kinds of rules need to be established for managing fisheries? How do different harvest rates affect the stocks of fish?

Land economics: How do people in the private sector (builders, home purchasers) make decisions about the use of land? How do the laws of property rights and public land use regulations affect the way space is devoted to different uses?

Energy economics: What are the appropriate rates for extracting underground petroleum deposits? How sensitive is energy use to changes in energy prices?

[1] Natural resource economics is the subject of a companion book written by one of the authors. See *Natural Resource Economics, An Introduction,* 2nd Ed., by Barry C. Field, Waveland Press, 2008.

Water economics: How do different water laws affect the way water is utilized by different people? What kinds of regulations should govern the reallocation of water from, for example, agriculture to urban users?

Agricultural economics: How do farmers make decisions about using conservation practices in cultivating their land? How do government programs affect the choices farmers make regarding what crops to produce and how to produce them?

A fundamental distinction in natural resource economics is that of **renewable** and **nonrenewable** resources. The living resources, such as fisheries and timber, are renewable; they grow in time according to biological processes. Some nonliving resources are also renewable—the classic example being the sun's energy that reaches the earth. Nonrenewable resources are those for which there are no processes of replenishment—once used they are gone forever. Classic examples are petroleum reservoirs and nonenergy mineral deposits. Certain resources, such as many groundwater aquifers, have replenishment rates that are so low that they are in effect nonrenewable.

It is easy to see that the use of nonrenewable resources is a problem with a strong **intertemporal** dimension; it involves trade-offs between the present and the future. If more oil is pumped out of an underground deposit this year, less will be available to extract in future years. Establishing today's correct pumping rate, therefore, requires a comparison of the value of oil now with the anticipated value of oil in the future.

But complicated intertemporal trade-offs also exist with renewable resources. What should today's codfish harvesting rate be, considering that the size of the remaining stock will affect its future growth and availability? Should this timber be cut today or does its expected rate of growth warrant holding off harvesting until some time in the future? Biological and ecological processes create connections between the rates of resource use in the present and the quantity and quality of resources available to future generations. It is these connections that are the focus of what has come to be called **sustainability.**

A resource use rate that is sustainable is one that can be maintained over the long run without impairing the fundamental ability of the natural resource base to support future generations. Sustainability does not mean that resources must remain untouched; rather, it means that their rates of use be chosen so as not to jeopardize future generations. In the case of nonrenewable resources, this implies using the extracted resource in such a way that it contributes to the long-run economic and social health of the population. For renewable resources, it means establishing rates of use that are coordinated with the natural productivity rates affecting the way the resources grow and decline.

Many environmental problems also have strong intertemporal dimensions, that is, important trade-offs between today and the future. For example, many pollutants tend to accumulate in the environment rather than dissipate and disappear. Heavy metals, for example, can accumulate in water and soil. Carbon dioxide emissions over many decades have accumulated in the earth's atmosphere. What is in fact being depleted here is the earth's **assimilative capacity,** the ability of the natural system to accept certain pollutants and render them benign or inoffensive. Some of the theoretical ideas about the depletion of natural resources are also useful in understanding environmental pollution. In this sense assimilative capacity is a natural resource akin to traditional resources such as oil deposits and forests.

A resource that has only recently impressed itself upon us is one that resides not in any one substance but in a collection of elements: **biological diversity.** Biologists estimate that there may be as many as 30 million different species of living organisms in the world today. These represent a vast and important source of genetic information that is useful for the development of medicines, natural pesticides, resistant varieties of plants and animals, and so on. Human activities have substantially increased the rate of species extinctions, so habitat conservation and species preservation have become important contemporary resource problems.

One feature of the modern world is that the dividing line between natural resources and environmental resources is blurring in many cases. Many resource extraction processes, such as timber cutting and strip mining, have direct repercussions on environmental quality. In addition, there are many instances where environmental pollution or disruption has an impact on resource extraction processes. Estuarine water pollution that interferes with the replenishment of fish stocks is an example, as is air pollution that reduces agricultural yields. Furthermore, certain things, such as wildlife, may be considered both natural resources and attributes of the environment. In recent years there has been a substantial shift in public concern away from natural resource use in the traditional sense and toward **natural resource preservation.** This can be regarded as both a natural resource and an environmental decision.

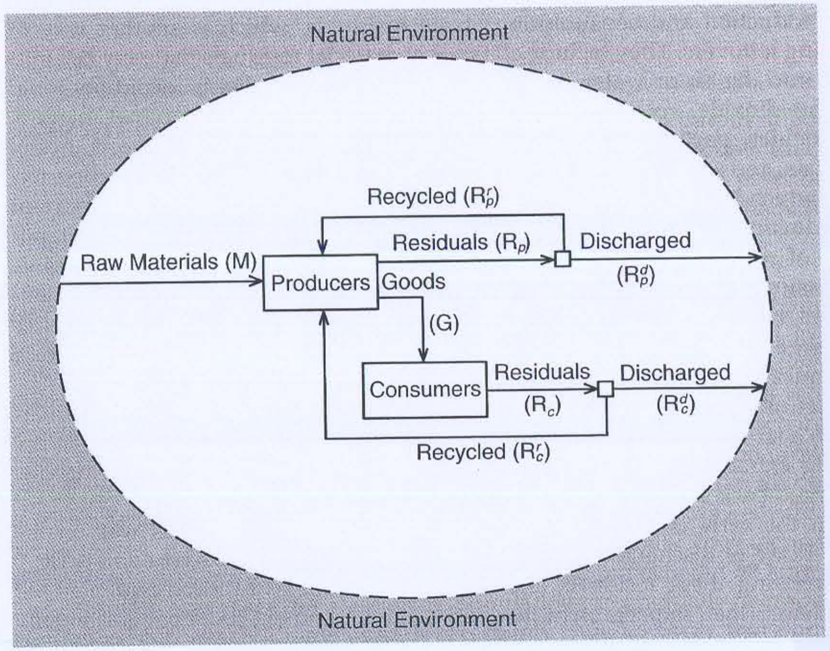
Despite the very close connections, however, the distinction that economists have made between these two services of the natural world—as raw materials and as environment—is sufficiently strong and well developed that it makes sense for us to proceed with a book that focuses primarily on the latter. We begin by considering a somewhat more complicated version of the simple diagram depicted at the beginning of the chapter.

The Fundamental Balance

In this book you will find a lot of simple analytical models of situations that in reality are somewhat complex. A model is a way of trying to show the essential structure and relationships in something, without going into all of its details, much as a caricature of a person accentuates distinguishing features at the cost of all the details.

Figure 2.1 is a more complex rendering of the relationships shown at the beginning of the chapter. The elements within the circle are parts of the economic system, the whole of which is basically encapsulated within the natural environment. The economy has been divided into two broad segments, **producers** and **consumers.**

FIGURE 2.1 The Environment and the Economy



- The producers category includes all private firms that take inputs and convert them to outputs; it also includes units such as public agencies; nonprofit organizations; and firms producing services, such as transportation. The primary inputs from the natural environment to the producing sector are materials, in the form of fuels, nonfuel minerals, and wood; fluids (e.g., water and petroleum); and gases of various types (e.g., natural gas and oxygen). All goods and services are derived from materials with the application of energy inputs.
- The consumers category includes all of the private households to whom the vast collections of final goods and services are distributed. One could argue that consumers sometimes use inputs directly from nature, like producers; many households, for example, get their water supplies directly from groundwater aquifers rather than water distribution companies. In the interest of keeping the model simple, however, we have not drawn this type of relationship.

It needs to be kept in mind that producers and consumers actually consist of the same people in different capacities. The "us vs. them" quality that characterizes many environmental disputes is really an internal disagreement within a single group. Society as a whole is essentially in the same position as a single household that pumps water from its own well and discharges wastes into its own septic system, which happens to be near the well.

Production and consumption create **residuals,** which is another way of saying leftovers. They include all types of material residuals that may be emitted into the air or water or disposed of on land. The list is incredibly long: sulfur dioxide, volatile organic compounds, toxic solvents, animal manure, pesticides, particulate matter of all types, waste building materials, heavy metals, and so on. Waste energy in the form of heat and noise, and radioactivity, which has characteristics of both material and energy, are also important production residuals. Consumers are also responsible for enormous quantities of residuals, chief among which are domestic sewage and automobile emissions. All materials in consumer goods must eventually end up as leftovers, even though they may be recycled along the way. These are the source of large quantities of solid waste as well as hazardous materials such as toxic chemicals and used oil.

Let us first consider the question of production and consumption residuals from a strictly physical standpoint. Figure 2.1 shows raw materials and energy being extracted from the natural environment (M) and residuals being discharged back into the environment.

In the early days of environmental concern, the main focus was on the end flows of discharged residuals by producers (R_p^d) and by consumers (R_c^d). By treating these residuals and otherwise changing the time and place of discharge, their impacts on humans and the environment could be substantially changed. While this is still an important locus of activity, recent years have seen a broadening of perspective to what is called **environmental management.**

To appreciate this broadening of focus, let us consider the flows of Figure 2.1 in greater detail. From physics, the law of the conservation of matter assures us that, in the long run, these two flows must be equal. In terms of the symbols of Figure 2.1:[2]

$$M = R_p^d + R_c^d$$

We must say "in the long run" for several reasons. If the system is growing, it can retain some proportion of the natural inputs, which go toward increasing the size of the system through a growing population, the accumulation of capital equipment, and so on. These would be disposed of if and when the system ceases to grow. Also, recycling can obviously delay the disposal of residuals. But recycling can never be perfect; each cycle must lose some proportion of the recycled material. Thus, the fundamental **materials/energy balance** equation must hold in the long run. This shows us something very fundamental: To reduce the mass of residuals disposed of in the natural environment, it is necessary to reduce the quantity of raw materials taken into the system.[3]

[2] To make these direct comparisons all flows must be expressed in terms of mass.

[3] Note that $G = R_c$, that is, everything that flows to the consumption sector eventually ends up as a residual from that sector.

To look more closely at the various options for doing this, substitute for M. According to the flow diagram,

$$R_p^d + R_c^d = M = G + R_p - R_p^r - R_c^r$$

which says that the quantity of raw materials (M) is equal to output of goods and services (G) plus production residuals (R_p), minus the amounts that are recycled from producers (R_p^r) and consumers (R_c^r). There are essentially three ways of reducing M and, therefore, residuals discharged into the natural environment.

Reduce G Assuming the other flows stay the same, we can reduce residuals discharged by reducing the quantity of goods and services produced in the economy. Some people have fastened on this as the best long-run answer to environmental degradation; reducing output, or at least stopping its rate of growth, would allow a similar change in the quantity of residuals discharged. Some have sought to reach this goal by advocating "zero population growth" (ZPG).[4] A slowly growing or stationary population can make it easier to control environmental impacts, but for two reasons it does not in any way ensure this control. First, a stationary population can grow economically, thus increasing its demand for raw materials. Second, environmental impacts can be long-run and cumulative, so that even a stationary population can gradually degrade the environment in which it finds itself. It is certainly true, however, that population growth will often exacerbate the environmental impacts of a particular economy. In the U.S. economy, for example, although the emissions of pollutants per car have dramatically decreased over the last few decades through better emissions-control technology, the sheer growth in the number of cars on the highways has led to an increase in the total quantity of automobile emissions in many regions.

Reduce R_p Another way of reducing M, and therefore residuals discharged, is to reduce R_p. Assuming the other flows are held constant, this means essentially changing the amounts of production residuals produced for a given quantity of output produced. There are basically only two ways of doing this.

- Reduce the **residuals intensity of production** in all sectors of the economy by inventing and adopting new production technologies and practices that leave smaller amounts of residuals per unit of output produced. For example, in later discussions of CO_2 emissions and atmospheric warming, we will see that there is much that can be done to reduce the CO_2 output per unit of output produced, especially by shifting to different fuels, but also by

[4] For example, see Herman E. Daly, *Steady State Economics, Second Edition with New Essays*, Island Press, Washington, DC, 1991.

reducing (actually by continuing to reduce) the quantities of energy required to produce a unit of final output. This approach has come to be called **pollution prevention,** or **source reduction.**

- Shift the composition of final output; that is, reduce those sectors that have relatively high residuals per unit of output and expand those sectors that produce relatively few residuals per unit of output. Output G actually consists of a large number of different goods and services, with great differences among them in terms of the residuals left after they are produced. So another way to reduce the total quantity of residuals is to shift the composition of G away from high-residuals items and toward low-residuals items, while leaving the total intact. The shift from primarily a manufacturing economy toward services is a step in this direction. This is called a **sectoral shift,** because it changes the relative shares of the different economic sectors in the aggregate economy. The rise of the so-called information sectors is another example. It is not that these new sectors produce no significant residuals; indeed, some of them may produce harsher leftovers than we have known before. The computer industry, for example, uses a variety of chemical solvents for cleaning purposes. But on the whole these sectors probably have a smaller waste disposal problem than the traditional industries they have replaced.

Increase $(R_p^r + R_c^r)$ The third possibility is to increase recycling. Instead of discharging production and consumption residuals into the environment, they can be recycled back into the production process. What this shows is that the central role of recycling is to replace a portion of the original flow of virgin materials (M). By substituting recycled materials for virgin materials, the quantity of residuals discharged can be reduced while maintaining the rate of output of goods and services (G). In modern economies recycling offers great opportunities to reduce waste flows. But we have to remember that recycling can never be perfect, even if enormous resources were devoted to the task. Production processes usually transform the physical structure of materials inputs, making them difficult to use again. The process of energy conversion changes the chemical structure of energy materials so thoroughly that recycling is impossible. In addition, recycling processes themselves can create residuals. But materials research will continue to progress and discover new ways of recycling. For a long time, automobile tires could not be recycled because the original production process changed the physical structure of the rubber. But recently new technological means have been found so that vast quantities of used tires, instead of blighting the landscape, can be incorporated into park benches, roads, and other products.

These fundamental relationships are very important. We must remember, however, that our ultimate goal is to reduce the damages caused by the discharge of production and consumption residuals. Reducing the total quantity of these residuals is one major way of doing this, and the relationships discussed

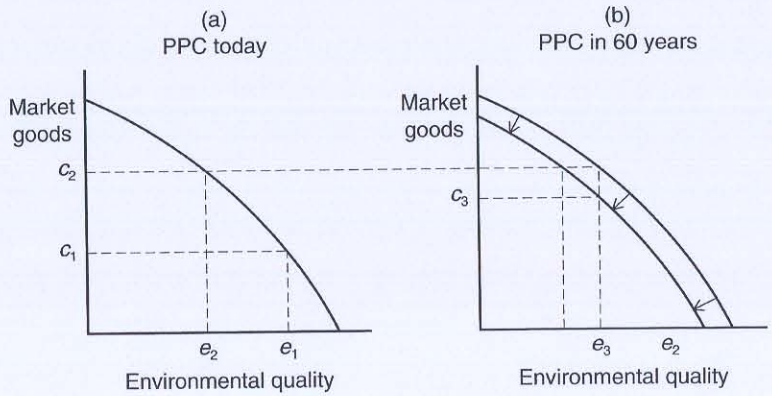
indicate the basic ways this may be done. But damages also can be reduced by working directly on the stream of residuals, a fact that must be kept in mind in our later discussions.

The Environment as an Economic and Social Asset

One good way of thinking about the environment is as an asset that produces important services for humans and nonhuman organisms. But the ability of the environment to produce these services can be degraded. In recent years the concept of **sustainability** has become popular as a criterion for evaluating decisions that have environmental implications. Sustainability is a matter of making decisions in the short run that do not have serious negative impacts in the long run.

A way of thinking about this is in terms of a **trade-off** between conventional economic output (conventional goods and services such as cars, loaves of bread, insurance policies, etc.) and environmental quality. A trade-off of this type is depicted in Figure 2.2. Consider first panel (a). This shows a **production possibility curve** (PPC), which is simply a curve showing the different combinations of two things a society may produce at any time, given its resources and technological capabilities. The vertical axis has an index of the aggregate output of an economy, that is, the total market value of conventional economic goods traded in the economy in a year. The horizontal axis has an index of environmental quality, derived from data on different dimensions of the ambient environment, for example, airborne SO_2 concentrations, urban noise levels, and water quality data. The curved relationship shows the different combinations of these two outcomes—marketed output and environmental quality—that are available to

FIGURE 2.2 Production Possibility Curves for Current and Future Generations



a group of people who have a fixed endowment of resources and technology with which to work.[5]

The exact shape and location of the production possibility curve are determined by the **technical capacities** in the economy, together with the ecological facts—meteorology, hydrology, and so on—of the natural system in which the society is situated. It says, for example, that if the current level of economic output is c_1, an increase to c_2 can be obtained only at the cost of a decrease in environmental quality from e_1 to e_2. One major objective of any society, of course, is to change the production possibility curve so that the underlying trade-off is more favorable—in other words, so that a given economic output is consistent with higher levels of environmental quality.

Although the PPC itself is a technical constraint, where a society chooses to locate itself on its PPC is a matter of **social choice.** This depends on the values that people in that society place on conventional economic output as opposed to environmental quality. Where values come from is an open question, but it is clear that values differ from one person to another and even for the same person at different points in time. The study of the values that people place on environmental factors is a major part of environmental economics and will be discussed in more detail in Chapters 7 and 8.

Another matter of concern is that current measures of **aggregate economic output** typically contain only measures of quantities of market goods. This is because the prices of these goods and services are provided by the markets in which they are traded, so their aggregate values can be assessed quite easily. Environmental quality, on the other hand, is generally a **nonmarket** type of outcome, in the sense that elements of environmental quality do not trade directly on markets where prices could be evaluated. If a society puts too much stress on increasing its measured output, it may end up at a point like (c_2, e_2) in Figure 2.2, panel (a), even though true social welfare may be higher at a point like (c_1, e_1).

Production possibility curves can also be used to elucidate other aspects of social choice about the environment. One of the fundamental distinctions that can be made in environmental analysis and the development of environmental policy is that between the **short run** and the **long run.** Short-run decisions are those made on the basis of consequences that happen in the near term or of impacts as they are felt by the present generation. Long-run decisions are those in which attention is paid to consequences that occur well into the future or to future generations. There is a widespread feeling that economic decisions today are being made primarily through short-run considerations, whereas environmental policy needs to be made with long-run considerations in mind. A good way of thinking about this is through the use of production possibility curves, introduced above.

Consider again Figure 2.2. The two panels actually show production possibility curves for two time periods. Panel (a) shows the trade-offs facing the current generation. Panel (b) shows the production possibility curves for people in, say, 60 to 80 years, the generation consisting of your great grandchildren. According to panel (a), the present generation could choose combinations (c_1, e_1), (c_2, e_2), or any others on the curve. But the future is not independent of the choice made today. It is conceivable, for example, that degrading the environment too much today will affect future possibilities—by depleting certain important resources, by pollution that is so high it causes irreversible damage, or simply by a pollutant that is very long-lived and affects future generations. In effect this could shift the future PPC back from where it otherwise would be. This is depicted in panel (b) of the diagram. Your grandchildren will be confronted with a reduced set of possibilities as compared to the choices we face today. The future generation, finding itself on the inner production possibilities curve, can still have the same level of marketed output we have today (c_2), but only at a lower level of environmental quality (e_3) than we have today. Alternatively, it could enjoy the same level of environmental quality, but only with a reduced level of marketed output (c_3).

[5] The extremes of the PPC are drawn with dashed lines. It's not clear what an outcome would be with "zero" environmental quality, or with "zero" economic output. Thus, these extreme points are essentially undefined, and we focus on points in the interior of the diagram.

It needs to be recognized, of course, that the influence of today's decisions on future production possibilities is much more complicated than this discussion might suggest. It's not only environmental degradation that affects future conditions, but also technical developments and changes in human capacities. Thus, today's decisions could shift the future PPC either in or out, depending on many dynamic factors that are hard to predict. But we need to be particularly alert to avoid decisions today that would have the effect of shifting the future PPC to the left. This is the essence of recent discussions about **sustainability.** Sustainability means that future production possibility curves are not adversely affected by what is done today. It does not mean that we must maximize environmental quality today, because that implies zero output of goods and services. It means simply that environmental impacts need to be reduced enough today to avoid shifting future production possibility curves back in comparison to today's production possibilities. We will meet the idea of sustainability at several points throughout this book.

Terminology

Throughout the chapters that follow we use the following terms:

- **Ambient quality:** *Ambient* refers to the surrounding environment, so ambient quality refers to the quantity of pollutants in the environment, for example, the concentration of SO_2 in the air over a city or the concentration of a particular chemical in the waters of a lake.
- **Environmental quality:** A term used to refer broadly to the state of the natural environment. This includes the notion of ambient quality and such things as the visual and aesthetic quality of the environment.
- **Residuals:** Material that is left over after something has been produced. A plant, for example, takes in a variety of raw materials and converts these into

some product. Materials and energy left after the product has been produced are *production residuals. Consumption residuals* are whatever is left over after consumers have finished using the products that contained or otherwise used these materials.

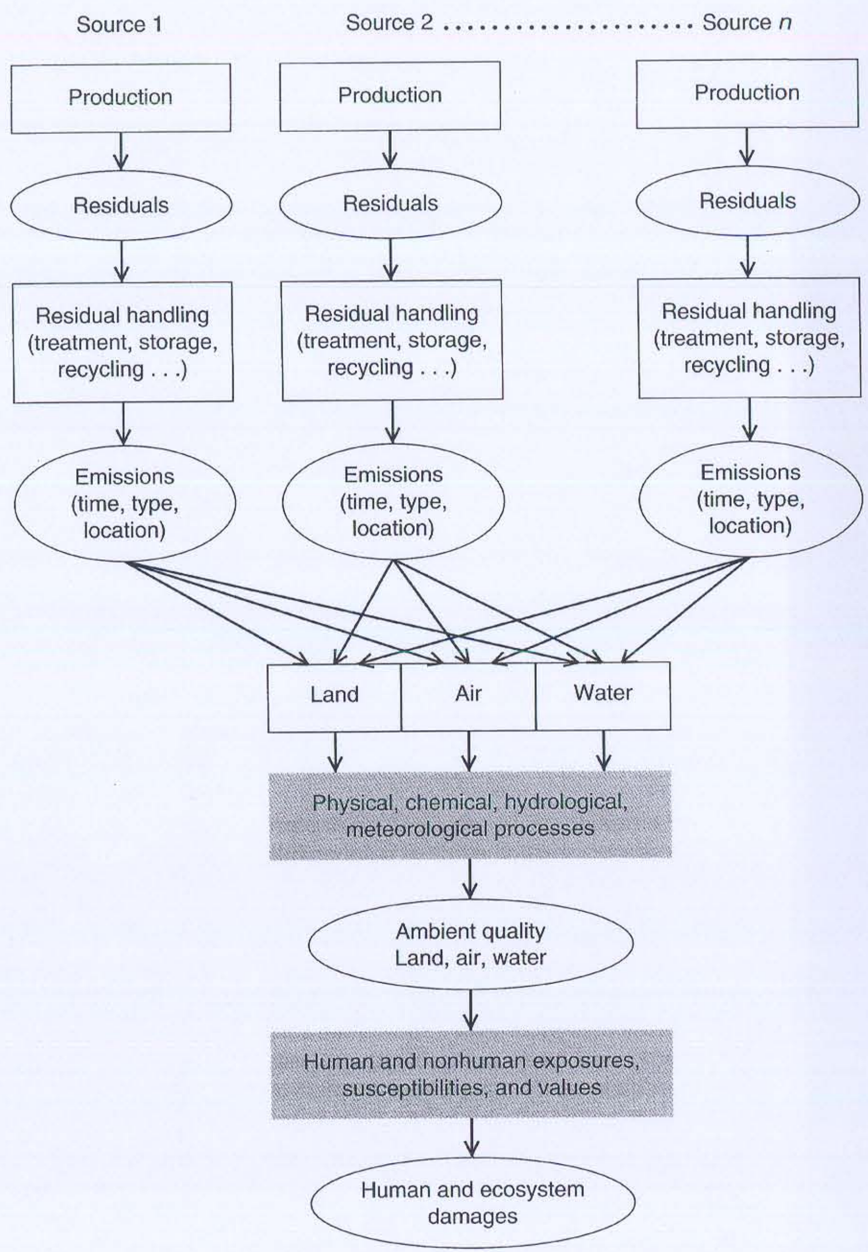
- **Emissions:** The portion of production or consumption residuals that is placed in the environment, sometimes directly, sometimes after treatment.
- **Recycling:** The process of returning some or all of the production or consumption residuals to be used again in production or consumption.
- **Pollutant:** A substance, energy form, or action that, when introduced into the natural environment, results in a lowering of the ambient quality level. We want to think of this as including not only the traditional things, such as oil spilled into oceans or chemicals placed in the air, but also activities, such as certain building developments, that result in "visual pollution."
- **Effluent:** Sometimes *effluent* is used to talk about water pollutants, and *emissions* to refer to air pollutants, but in this book these two words are used interchangeably.
- **Pollution:** *Pollution* is actually a tricky word to define. Some people might say that pollution results when any amount, no matter how small, of a residual has been introduced into the environment. Others hold that pollution is something that happens only when the ambient quality of the environment has been degraded enough to cause some damage.
- **Damages:** The negative impacts produced by environmental pollution on people in the form of health effects, visual degradation, and so on, and on elements of the ecosystem through disruption of ecological linkages, species extinctions, and so forth.
- **Environmental medium:** Broad dimensions of the natural world that collectively constitute the environment, usually classified as land, water, and air.
- **Source:** The location at which emissions occur, such as a factory, an automobile, or a leaking landfill.

Emissions, Ambient Quality, and Damages

Let us now focus on what happens at the end of those two discharge arrows at the right side of Figure 2.1. Very simply, **emissions** produce changes in ambient levels of environmental quality, which in turn cause damages to humans and nonhumans. Figure 2.3 shows one way of sketching out this relationship. It shows *n* sources of emissions;[6] they might be private firms, government agencies, or consumers. Sources take in various inputs and use different types of technologies in production and consumption. In the process they produce residuals. How these residuals are handled then has a critical effect on subsequent stages. Some may be recovered and recycled back into production or consumption.

[6] In economic writing, the letter *n* is often used to designate an unspecified number of items, the exact value of which will vary from one situation to another.

FIGURE 2.3 **Emissions, Ambient Quality, and Damages**



Source: *Inspired by John B. Braden and Kathleen Segerson, "Information Problems in the Design of Non-point Source Pollution Policy," in Association of Environmental and Resource Economics (AERE) Workshop Papers,* The Management of Non-point Source Pollution, Lexington, June 6–7, 1991.

Many can be put through treatment processes (residuals handling) that can render them more benign when emitted. Some of these processes are strictly physical (mufflers on cars and trucks, settling ponds at wastewater treatment plants, catalytic converters); others involve chemical transformations of various types (advanced treatment of domestic wastewater).

All emissions must necessarily go into one or more of the different **environmental media,** and there is an important relationship among them. There is a natural tendency in policy deliberations to keep these different media in separate compartments, dealing with air pollution separately from water pollution, and so on. But they are obviously interconnected; once residuals are produced, all that are not recycled must end up being discharged into one or more of the different media. Thus, for a given quantity of total residuals, if the amounts going into one medium are reduced, the amounts going into the others must necessarily increase. When sulfur dioxide (SO_2) is removed from the stack gases of power plants, for example, the sulfur compounds have not been destroyed. Instead, we end up with a sulfurous sludge that must be disposed of some other way, perhaps by land burial. If this material is incinerated, airborne emissions result, but there will still be certain quantities of solid residuals that must be disposed of elsewhere.

In a situation involving multiple sources, emissions will often become mixed into a single flow. In the real world this mixing may be complete; for example, the effluent from two pulp mills located at the same point on a river may mix so thoroughly that a few miles downstream it is impossible to differentiate one source's effluent from the other's. When there are a million or so cars moving about an urban area, the emissions from all become uniformly mixed together. In other cases the mixing is less than complete. If one power plant is just outside the city and another is 20 miles upwind, the closer plant will normally bear a greater responsibility for deteriorating air quality in the city than the other.

This mixing of emissions is a more significant problem than might first appear. With just a single source, the line of responsibility is clear, and to get an improvement in ambient quality we know exactly whose emissions have to be controlled. But with multiple sources, responsibilities become less clear. We may know how much we want to cut back total emissions, but the problem of distributing this total reduction among the different sources still exists. Each source then has an incentive to get the others to bear a larger share of the burden of reducing emissions. With every source thinking along the same lines, pollution control programs face a real problem of design and enforcement. We will run into this problem many times in the chapters to come.

Once a given quantity and quality of residuals have been introduced into a particular environmental medium, it is the physical, chemical, biological, meteorological, and so on, processes of the natural system that determine how the residuals translate into particular **ambient quality levels.** For example, wind and temperature conditions will affect whether and how residuals emitted into the air affect nearby neighborhoods, as well as people living farther downwind. In addition, because these meteorological conditions vary from day to day, the

same level of emissions can produce different ambient quality levels at different times. Acid rain is produced through chemical processes acting primarily on sulfur dioxide emissions emitted far upwind; smog is also the result of complex chemical reactions involving sunlight and quantities of various pollutants. Underground hydrological processes affect the transportation of materials disposed of in landfills. And so on. Thus, to know how particular emissions will affect ambient quality levels, we must have a good understanding of the physical and chemical workings of the environment itself. This is where the natural and physical sciences come in—to study the full range of environmental phenomena, from small, localized models of groundwater flow in a particular aquifer, to complex models of large lakes and river basins, to studies of interregional wind patterns, to global climate models. The fundamental goal is to determine how particular patterns of emissions are translated into corresponding patterns of ambient quality levels.

Finally, there are **damages.** A given set of ambient conditions translates into particular exposure patterns for living and nonliving systems. Of course, these exposures are a function not only of the physical processes involved, but also of the human choices that are made about where and how to live, and of the susceptibilities of living and nonliving systems to varying environmental conditions. Lastly, damages are related to human values. Human beings do not have amorphous preferences over all possible outcomes of the economic/environmental interaction; they prefer some outcomes over others. A major part of environmental economics is trying to determine the relative values that people place on these different environmental outcomes, a subject to which we will turn in later chapters on benefit–cost analysis.

Types of Pollutants

Physically, the residuals identified in Figure 2.3 consist of a vast assortment of materials and energy flowing into the three environmental media. It is helpful to distinguish among broad types of emissions according to factors that critically affect their economic characteristics.

Cumulative vs. Noncumulative Pollutants

One simple and important dimension of environmental pollutants is whether they accumulate over time or tend to dissipate soon after being emitted. The classic case of a **noncumulative pollutant** is noise; as long as the source operates, noise is emitted into the surrounding air, but as soon as the source is shut down, the noise stops. At the other end of the spectrum there are pollutants that cumulate in the environment in nearly the same amounts as they are emitted. Radioactive waste, for example, decays over time but at such a slow rate in relation to human life spans that for all intents and purposes it will be with us permanently; it is a strictly cumulative type of pollutant. Another **cumulative pollutant** is plastics. The search for a degradable plastic has been going on for decades, but so far plastic is a substance that decays very slowly by human standards; thus, what we dispose of will be in the environment permanently. Many chemicals are cumulative pollutants; once emitted they are basically with us forever.

Between these two ends of the spectrum there are many types of effluent that are to some extent, but not completely, cumulative. The classic case is organic matter emitted into water bodies; for example, the wastes, treated or not, emitted from municipal waste treatment plants. Once emitted the wastes are subject to natural chemical processes that tend to break down the organic materials into their constituent elements, thus rendering them much more benign. The water, in other words, has a natural assimilative capacity that allows it to accept organic substances and render them less harmful. As long as this assimilative capacity has not been exceeded in any particular case, the effluent source can be shut off, and in a few days, weeks, or months the water quality will return to normal. Once emissions exceed this assimilative capacity, however, the process becomes cumulative.

Whether a pollutant is cumulative or noncumulative, the basic problem is essentially the same: trying to figure out the environmental damages and relating these back to the costs of reducing emissions. But this job is much more difficult for cumulative than for noncumulative pollutants. With noncumulative emissions, ambient concentrations are strictly a function of current emissions—reducing these emissions to zero would lead to zero ambient concentrations. But with cumulative pollutants the relationship is more complex. The fact that a pollutant cumulates over time in the environment has the effect of breaking the direct connection between current emissions and current damages. This has a number of implications. For one thing it makes the science more difficult. The cause-and-effect relationships become harder to isolate when there is a lot of time intervening between them. It also may make it more difficult to get people to focus on damages from today's emissions, again because there may only be a weak connection between today's emissions and today's ambient quality levels. Furthermore, cumulative pollutants by definition lead to future damages, and human beings have shown a depressing readiness to discount future events and avoid coming to grips with them in the present.

Local vs. Regional and Global Pollutants

Some emissions have an impact only in restricted, localized regions, whereas others have an impact over wider regions, perhaps on the global environment. Noise pollution and the degradation of the visual environment are local in their impacts; the damages from any particular source are usually limited to relatively small groups of people in a circumscribed region. Note that this is a statement about how widespread the effects are from any particular pollution source, not about how important the overall problem is throughout a country or the world. Many pollutants, on the other hand, have widespread impacts, over a large region or perhaps over the global environment. Acid rain is a regional problem; emissions in one region of the United States (and of Europe) affect people in other parts of the country or region. The ozone-depleting effects of chlorofluorocarbon emissions from various countries work through

chemical changes in the earth's stratosphere, which means that the impacts are truly global.

Other things being equal, local environmental problems ought to be easier to deal with than regional or national problems, which in turn ought to be easier to manage than global problems. If I smoke out my neighbor with my wood stove, we may be able to arrange a solution among ourselves, or we can call on local political institutions to do it. But if my behavior causes more distant pollution, solutions may be more difficult. If we are within the same political system, we can call on these institutions to arrange solutions. In recent years, however, we have been encountering a growing number of international and global environmental issues. Here we are far from having effective means of responding, both because the exact nature of the physical impacts is difficult to describe and because the requisite international political institutions are only beginning to appear.

Point-Source vs. Nonpoint-Source Pollutants

Pollution sources differ in terms of the ease with which actual points of discharge may be identified. The points at which sulfur dioxide emissions leave a large power plant are easy to identify; they come out the end of the smokestacks associated with each plant. Municipal waste treatment plants normally have a single outfall from which all of the wastewater is discharged. These are called **point-source pollutants.** There are many pollutants for which there are no well-defined points of discharge. Agricultural chemicals, for example, usually run off the land in a dispersed or diffused pattern, and even though they may pollute specific streams or underground aquifers, there is no single pipe or stack from which these chemicals are emitted. This is a **nonpoint-source** type of pollutant. Urban storm water runoff is also an important nonpoint-source problem.

As one would expect, point-source pollutants are likely to be easier to come to grips with than nonpoint-source pollutants. They will probably be easier to measure and monitor and easier to study in terms of the connections between emissions and impacts. This means that it will ordinarily be easier to develop and administer control policies for point-source pollutants. As we will see, not all pollutants fit neatly into one or another of these categories.

Continuous vs. Episodic Emissions

Emissions from electric power plants or municipal waste treatment plants are more or less continuous. The plants are designed to be in operation continuously, although the operating rate may vary somewhat over the day, week, or season. Thus, the emissions from these operations are more or less continuous, and the policy problem is to manage the rate of these discharges. Immediate comparisons can be made between control programs and rates of emissions. The fact that emissions are continuous does not mean that damages are also continuous, however. Meteorological and hydrological events can turn continuous emissions into uncertain damages. But control programs are often easier to carry out when emissions are not subject to large-scale fluctuations.

Many pollutants are emitted on an episodic basis, however. The classic example is accidental oil or chemical spills. The policy problem here is to design and manage a system so that the probability of accidental discharges is reduced. Yet, with an episodic effluent there may be nothing to measure, at least in the short run. Even though there have been no large-scale radiation releases from U.S. nuclear power plants, for example, there is still a "pollution" problem if they are being managed in such a way as to increase the **probability** of an accidental release in the future. To measure the probabilities of episodic emissions, it is necessary to have data on actual occurrences over a long time period or to estimate them from engineering data and similar information. We then have to determine how much insurance we wish to have against these episodic events.

Environmental Damages Not Related to Emissions

So far the discussion has focused on the characteristics of different types of environmental pollutants as they relate to the discharge of residual materials or energy, but there are many important instances of deteriorating environmental quality that are not traceable to residuals discharges. The conversion of land to housing and commercial areas destroys the environmental value of that land, whether it be its ecosystem value, such as habitat or wetland, or its scenic value. Other land uses, such as logging or strip mining, also can have important impacts. In cases such as these, the policy problem is still to understand the incentives of people whose decisions create these impacts and to change these incentives when appropriate. Although there are no physical emissions to monitor and control, there are nevertheless outcomes that can be described, evaluated, and managed with appropriate policies.

Summary

The purpose of this chapter was to explore some basic linkages between the economy and the environment. We differentiated between the role of the natural system as a supplier of raw material inputs for the economy and as a receptor for production and consumption residuals. The first of these is normally called natural resource economics and the second environmental economics. After a very brief review of natural resource economics, we introduced the fundamental balance phenomenon, which says that in the long run all materials taken by human beings out of the natural system must eventually end up back in that system. This means that to reduce residuals flows into the environment we must reduce materials taken from the ecosystem, and we discussed the three fundamental ways that this can be done. This led into a discussion of the inherent trade-off that exists between conventional economic goods and environmental quality and between current and future generations.

We then focused more directly on the flow of residuals back into the environment, making a distinction among emissions, ambient environmental quality, and damages. The environmental damages from a given quantity of emissions

can be very substantially altered by handling these emissions in different ways. Our next step was to provide a brief catalog of the different types of emissions and pollutants, as well as nonpollution types of environmental impacts such as aesthetic effects.

Questions for Further Discussion

1. Economies grow by investing in new sources of productivity, new plants and equipment, infrastructure such as roads, and so on. How does this type of investment affect the flows depicted in Figure 2.1?
2. What is the difference between a residual and a pollutant? Illustrate this in the context of a common airborne emission such as sulfur dioxide (SO_2); with noise; with junked automobiles; with an unsightly building.
3. Why are long-lived, cumulative pollutants so much harder to manage than short-lived, noncumulative pollutants?
4. As depicted in Figure 2.3, most emissions from individual sources get mixed in with those of other sources, to produce the general level of ambient quality. What problems does this present in adopting emission control policies to get a cleaner environment?
5. Considering the various general ways of reducing final emissions in Figure 2.1, illustrate these with a particular industrial product, such as cars.
6. What considerations come into play when considering whether the United States or any other political entity is spending the right amount for environmental quality improvements?
7. Suppose there is a technological change that allows firms to produce goods and services with less pollution. How would this affect the production possibilities curves of Figure 2.2, and where might society choose to locate itself on this curve?

For additional readings and Web sites pertaining to the material in this chapter see **www.mhhe.com/field5e**.