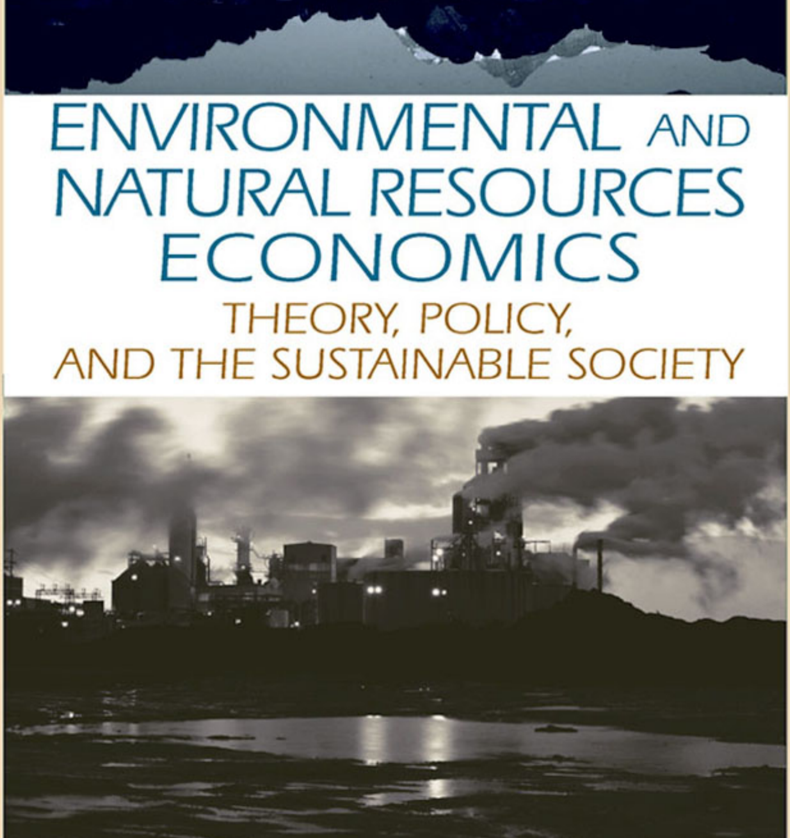
STEVEN C. HACKETT

ENVIRONMENTAL AND NATURAL RESOURCES ECONOMICS

THEORY, POLICY, AND THE SUSTAINABLE SOCIETY



2nd Edition

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THEORY, POLICY, AND THE SUSTAINABLE SOCIETY

2nd Edition

STEVEN C. HACKETT

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To my children, Tessa, Alexandra, and Caitlin

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Preface

This textbook provides an accessible yet rigorous treatment of environmental and natural resources economics, as well as the emerging subject of sustainability. Chapters 1 through 10 cover a traditional one-semester course in environmental and resource economics. A nontraditional course on the economics of a sustainable society can be built around chapters 1 through 3 (economic fundamentals), followed by chapters 11 through 15 (issues in the economics of a more sustainable society). Moreover, a number of topics can be added or subtracted based on the nature of the course being taught. For example, chapters 1 through 3 introduce basic principles, and they are included to make the book accessible to those who do not have a prior background in economics. If this book is to be used in an upper-division course for economics majors, students can cover these quickly as a review. Those who are teaching a more introductory course may want to skip parts of the efficiency analysis of markets with externalities in chapter 4, and the material on dynamic efficiency and Hotelling's rule in chapter 5.

This book reflects the experiences I have had with the diverse students of Humboldt State University. These include majors in business, economics, environmental science, forestry, and natural resources planning, among others. Many of these students lack any prior background in economics, and they approach the study of economics with a healthy dose of skepticism. Consequently, the approach is to evaluate economics from a broader perspective than is typical in economics textbooks, including both mainstream economic topics and topics that lie at the boundary with other disciplines and schools of thought. Examples of the broader approach can be seen in the coverage of philosophy in chapter 2, and the extensive material on sustainability in chapters 11 through 15. I have always appreciated it when authors provide citations so that I can explore the literature on a topic that I enjoy, and therefore, scholarly works are cited more frequently than may be common in most economic textbooks. Many scholarly works, policy studies, and government research documents are now available on the Internet, and so a list of annotated Internet links is provided at the end of each chapter. These Internet documents are also a good source of material for students who are required to write research essays. Those who are new to environmental and natural resources economics must develop a large new vocabulary, and to make that process easier and less frustrating an extensive glossary is provided at the end of the text.

A considerable amount of new material was added in creating the second edition of this work. The Internet has expanded since the first edition was written, and the Internet links added at the end of each chapter are a new feature in the second edition. In addition, many chapters now include a problem that requires students to acquire and interpret information from the Internet. The glossary has been expanded for this edition, and each chapter has been revised and updated. Among the more extensive changes introduced in the second edition, the case study on the economics of marine capture fisheries in chapter 5 has been expanded to include recent research on the performance of individual quota systems. The somewhat awkward treatment of dynamically efficient resource allocation and Hotelling's rule in chapter 5 has been rewritten. A supply-and-demand model has been developed to provide a better framework for understanding environmental political economy in chapter 7. The scientific and scholarly literature on global climate change has advanced a great deal since the first edition was written, and so chapter 10 has been revised and an extensive amount of new material has been added. Finally, there continues to be growth in ecolabeling programs; thus, that section of chapter 14 has been expanded.

An Internet site accompanies this textbook (http://www.humboldt.edu/~envecon). Readers will find helpful applications such as audio clips, Excel-based interactive simulations, lecture outlines, interactive quizzes, sample essays, annotated Internet links, and much more.

I would like to acknowledge the support and understanding of my family during the summer of 2000 when I was writing the second edition of this textbook. Dan Ihara supplied helpful comments on global climate change. Deborah Keeth provided capable research assistance, and helped me learn more about sustainable forestry. I would also like to thank my students for providing me with many new insights and helpful comments that have been integrated into the second edition.

Part I

Theory and Fundamentals

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1

Introduction to Environmental and Natural Resources Economics

Introduction

The traditional stereotype is that the economy and the environment are separate spheres, and that improvement in one sphere necessarily comes at a cost borne by the other. Traditionally, economists learned nothing about the environment, and environmental scientists and resource managers learned nothing about economics, which helped to maintain the stereotype. In this book you will come to learn that our economy rests upon the functional integrity of the world's ecosystems, that economic activity can have negative impacts on the environment, and that many aspects of our environment, including those not traded in markets, have economic value. You will see, for example, that essential ecosystem services such as nutrient cycling, sink functions of wetlands, and the hydrological cycle have economic value, and that some economists have started trying to estimate their value. You will also find out how markets for emission credits can be used to reduce the cost of compliance with environmental regulation, and understand the circumstances under which firms might actually lobby to impose more stringent environmental regulation on their industry. The relationship between economy and environment is much richer and more interesting than the traditional stereotype would have us believe. As Wendell Berry (1987) observes, "The thing that troubles us about the industrial economy is exactly that it is not comprehensive enough, that, moreover, it tends to destroy what it does not comprehend, and that it is *dependent* upon much that it does not comprehend" (pp. 54–55). It is hoped that this book will help introduce economists to relevant and important environmental issues, and to help resource and environmental specialists develop a basic competency in economics.

A number of themes covered in this book usually come together under the heading of "environmental and natural resources economics," and there are some that are still new and developing. A primary focus of this book is on *environmental economics*, which analyzes the economic basis for pollution and other human-induced harms to the natural environment, as well as the policies designed to resolve them. Much of the work in environmental economics studies the application and performance of incentive regulatory practices, such as pollution tax systems or pollution allowances markets, and the political economy of environmental policy. Another important focus of this book is on *natural resources economics*, which has traditionally addressed problems of governing common-pool natural resources, of finding dynamically optimal rates of resource extraction, and of the workings of resource and energy markets. More recently, *ecological economics* has struggled with understanding the economics of natural capital and the ecosystem services that flow from it. Another more recent area of inquiry, *the economics of a sustainable society*, includes efforts at identifying, modeling, and measuring the contribution of economic activities to a more sustainable society. People in a sustainable society enjoy nondiminishing flows of ecological, economic, sociopolitical, and cultural benefits. Accordingly, the economics of sustainability is concerned with understanding the interactions among economy, environment, and social/political institutions over the long term, and with using this information to fashion policies that move us closer to a sustainable society. Although some of these topics are complex, the text is also designed to be accessible to readers who may have little in the way of an economics background, but who possess a compensatory motivation to learn.

A number of threads of economic theory run through and link the various chapters of this book. One of these is the principle of pollution taxation, first introduced with externality theory in chapter 4. Various policy experiments in pollution taxation are described in chapter 9. More ambitious programs of ecological tax reform that call for a comprehensive shifting of taxes from beneficial activities such as employment to pollution and resource degradation are described in chapter 12. Another thread is the concept of dynamic efficiency, which is an adaptation of static efficiency concepts to resource management and other allocation choices that generate a flow of benefits and costs into the future. The theoretical concept is developed with regard to nonrenewable resources in chapter 5 and is also applied to benefit/cost analysis in chapter 6. The concept arises again in chapter 12, where it is related to sustainability. Related to the concept of dynamic efficiency, Hotelling rents occur when future demand for a scarce and depletable resource is reflected in current prices and represent the difference between the price and the marginal extraction cost of a resource. A theoretical model is developed in chapter 5 and applied again in chapter 13, where it is shown how reinvestment of Hotelling rents contributes to sustainability. Finally, the problem of governing common-pool resources (resources such as fisheries that are used by multiple people and are subject to depletion from overuse), first presented in chapter 5, is a recurrent theme throughout the remainder of the book.

The section that follows introduces some basic economic concepts. This section will help build a conceptual foundation for those who are new to economics. Readers with a prior background in economics may find it to be a useful review.

Fundamental Concepts

Many people approach economics with a preconceived notion of what economics is about. An example is the common tendency to equate economics with commercial activity and the stock market. These notions are embedded in our culture and in the various news media. The purpose of this section is to develop a clearer understanding of what economics is about. Let's start by defining economics:

ECONOMICS: The study of how scarce resources are allocated among competing uses.

The key issue in economics is that the choice problem of *how* to allocate is implied by the condition of *scarcity*, and so *economy* or minimization of waste occurs when resources are allocated to their highest-valued use. Thus, at the center of economics is *scarcity:*

SCARCITY: Something is said to be scarce when, at a zero price, more is wanted than is available.

Examples of scarcity:

- An instructor offers a candy bar to her class and discovers that six students want it.
- Class is called off, and a student can use that block of time to study, exercise, visit friends, do laundry, clean up her apartment, or nap.
- A popular mountain lake in a national forest wilderness area has two campsites, and six backpacking parties have arrived there to camp.
- An old-growth grove in a national forest can be logged to generate sub-

stantial income or preserved for recreation and habitat for certain old-growth dependent species.

- The gift of $100 that you receive for your birthday can be used for various combinations of clothing, food, entertainment, or travel.
- A small run of salmon in a river can be allocated to Native Americans, recreational fishers, commercial fishers, or seals and other wildlife.
- River water can be diverted to support irrigated agriculture or a municipal water supply, or it can be maintained as in-stream flow to enhance fishery and recreational activities.
- A hungry coyote with pups to feed must select from a wide variety of hunting areas and strategies in the context of a limited amount of time and energy.

In each of the cases given above, there is a choice problem necessitated by a condition of scarcity. It is interesting to note that the economic problem of allocating scarce resources in the context of competing uses is not unique to humans. Other forms of life also respond to conditions of scarcity, and one can argue that natural selection tends to favor those organisms that are most successful in allocating their time and energy in the context of scarcity. Scarcity is one of the fundamental aspects of our world, both inside and outside of markets. Scarcity makes choice unavoidable. While so many aspects of our world involve choices necessitated by a condition of scarcity, economics is fundamental and ever-present in most everything we do, whether we are aware of it or not. When you choose to buy a slice of pizza instead of a bowl of vegetarian chili for lunch, that is an economic decision. When the Forest Service chooses to manage a particular drainage for sensitive, wilderness-dependent species rather than for intense recreation or lumber production, that is an economic decision.

Because scarcity forces us to make choices from a set of alternatives, on what basis can we rank the various alternatives and choose the best one? Economic analysis requires a system of value from which we can compare alternatives and so distinguish good from not-as-good allocations. Every day you make economic choices that involve ranking alternatives. From a cognitive point of view many people develop decision rules and rules-of-thumb that simplify the process of ranking and choosing alternatives to such an extent that we are no longer consciously aware of those choices being made. Much of government policy-making involves the ranking of alternatives. Though people have different values, the best economic choice for one is not necessarily the best for another. As a consequence, environmental policy conflicts often have their basis in value conflicts, though they may be popularly cast as conflicts between economy and environment.

While economics is a very broad field of study, there is a tendency to more narrowly equate economics with commercial activity. For example, consider the following hypothetical headline: "*The decision to manage a segment of national forest as wilderness rather than as a timber production area is a rare example of the environment winning out over economics.*" The headline writer seems to be implying that wilderness values are noneconomic, confusing commerce with economics. This implication is false. The time and money that people spend in traveling to wilderness areas for recreation is scarce, as is the time and money spent by those who lobby and advocate for wilderness protection. People who do not visit wilderness areas nevertheless may value their existence. Wilderness areas also provide valuable ecosystem services and natural resources that flow beyond the wilderness boundary such as clean air, fresh water, wildlife, and plants. These and other wilderness benefits are no less economic than the price of admission to Disneyland or the revenues generated from a timber harvest. While markets are a prominent way of making allocation choices in the context of scarcity, economics encompasses the study of both market and nonmarket allocation of scarce resources. As Power (1996) observes, economic analysis of the environment is challenging and important precisely because its value is not conveniently revealed in a market and thus is subject to inappropriate use. Even wilderness area management itself is partly an economic problem. Managers have limited budgets to allocate for science and maintenance, and allocating a popular section of wilderness for threatened and endangered species habitat may require sharp cutbacks in recreational visitation. And so it should be clear that the lack of a market for wilderness does not mean that it has no economic value. In chapter 6 you will learn about various methods that have been developed for measuring the value of resources and other aspects of the environment that are not traded in markets, and so lack a market price as an indicator of value.

Continuing our example, protecting wild lands as wilderness means that certain extractive activities such as logging, mining, and ski-area development cannot occur. The value of these forgone options is part of the cost of wilderness protection, referred to as *opportunity cost.*

OPPORTUNITY COST: Something scarce can be allocated to a variety of different uses. When something scarce is allocated to one particular use, the opportunity cost of that choice is the value of the best alternative given up.

Everything that is scarce and so requires an allocation choice has an economic value that is reflected in opportunity cost. We can evaluate the rationality of a particular choice by comparing the benefits that it generates relative to its opportunity cost.

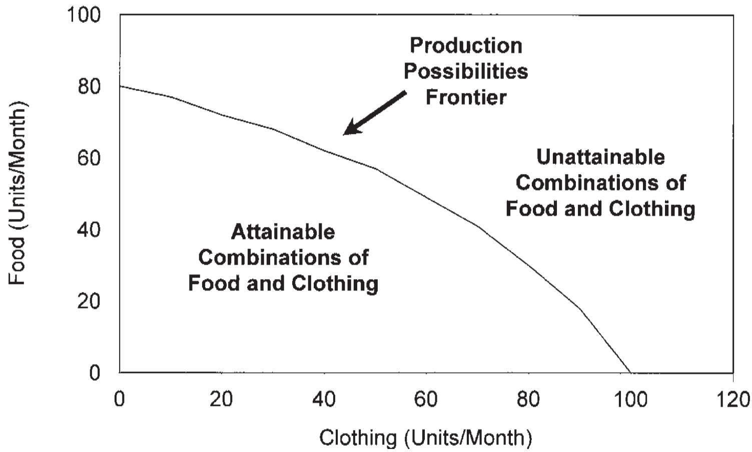
ECONOMIC RATIONALITY: A choice from competing options is said to be economically rational when it yields anticipated net benefits that exceed the opportunity cost.

Thus, economic rationality, as it is used in this book, refers to behavior that is intended to be consistent with the values and objectives of the decision maker, given the information that is available to the decision maker. Several issues are worth raising at this point. First, *rational* and *reasonable* do not mean the same thing. One person's rational choice may not seem reasonable to another who does not share the same values. Second, underlying the notion of economic rationality is the view that people (and economic organizations) are optimizers who have the objective of maximizing net value. In the context of markets, for example, neoclassical economics starts from the premise that consumers wish to maximize their overall level of satisfaction, or utility, as constrained by their income and by market prices, while firms wish to maximize their profits. From an economic point of view, however, optimizing behavior is not limited to market exchanges designed to improve material well-being; to believe that is to confuse optimization with self-interest. More often, optimization generally involves the process of ranking alternative uses of one's time, energy, attention, resources, or income based on a particular set of values and preferences, and then selecting the alternative that yields the greatest increase in net value. Thus, allocating scarce time and energy as a volunteer, a voter, or an activist can be entirely rational, optimizing behavior for those who care a great deal about their community.

The concepts of scarcity and opportunity cost can be illustrated in a *production possibilities frontier (PPF)*. In the simple illustrative example given in Figure 1.1, we have an economy that has a set of resources (land, labor, capital) that can be used to produce various combinations of food and clothing outputs.

The PPF in Figure 1.1 represents all the possible combinations of food and clothing that can be produced in a given time period when available resources are fully employed. When resources are wasted, such as when discrimination occurs and women are unable to obtain certain types of jobs for which they are qualified, we are inside rather than on the PPF. As we move along a PPF and increase the production of one good—such as clothing—we must shift resources away from producing the other good—namely, food. The opportunity cost of a given increase in clothing is reflected in the amount of food (and the value we place on it) that is given up to produce more clothing. Outward shifts in the PPF occur when more resources are available or when better technologies are developed that increase the productivity of a given resource. Preferences for food and clothing determine which combination along the frontier is produced in this highly simplified economy.

Figure 1.1 **Production Possibilities Frontier**



So what situations do *not* have an economic dimension? The answer is those things that are not scarce. Value systems, love, friendship, aspects of culture, and spirituality are, or at least can be, outside of economics because it is not clear that they are subject to scarcity. The range of possible thoughts and ideas is also not subject to scarcity, though it is clear that a person's cognitive capacities are scarce and thus subject to economics. Moreover, the assertion that economics is fundamental to the human experience does not necessarily imply that economists can measure and model everything of value that is affected by environmental and natural resources policy. In addition, the moral, ethical, and spiritual implications of a particular allocation problem may supersede the use of economic tools for determining what the proper allocation might be. This does not invalidate economic analysis, but acknowledges that social and political factors may play an equal or greater role in determining how a society ultimately chooses to allocate resources.

Some Reasons for Optimism and Some Reasons for Concern

In terms of trends, reasons exist for both optimism and concern. Let us first consider some reasons for being optimistic regarding economics and the environment.

Reasons for Optimism

One reason for being optimistic is that regulations such as the Clean Air Act and its amendments have led to substantial progress being made in reducing nationwide ambient air pollution concentrations in the United States. For example, the Council on Environmental Quality (1991) reported that between 1978 and 1990, U.S. ambient concentrations of particulates declined by 24 percent, sulfur dioxide declined by 39 percent, nitrogen oxides declined by 24 percent, carbon monoxide declined by 42 percent, lead declined by 93 percent, and ozone declined by 27 percent. Evidence shows that our investment in clean air has generated substantial economic benefits as well. In their benefit/cost analysis on the Clean Air Act, the Environmental Protection Agency (EPA) found that, over the period from 1970 to 1990, each dollar of compliance cost generated approximately $44.40 in economic benefits, largely from improved human health (U.S. Environmental Protection Agency, 1997).

Another reason for optimism is the decline in the rate of toxic releases for a given value of manufacturing output since the initiation of the Toxic Release Inventory (TRI) Program. Specifically, the Emergency Planning and Community Right-to-Know Act of 1986 requires firms to report releases of 320 different toxic chemicals. The TRI data were first released to the public in 1989, and analysis by Maxwell, Lyon, and Hackett (2000) indicates that beginning in 1989, a highly significant downward shift occurred in the relationship between the value of manufacturing output and toxic releases, indicating cleaner production.

The increasing cost-effectiveness of reducing sulfur dioxide emissions in the Environmental Protection Agency's Acid Rain Program offers another reason for optimism. As described in greater detail in chapter 9, the Acid Rain Program includes a novel approach to regulation that allows companies with lower cleanup costs to contract to perform cleanup for firms with very high cleanup costs. This market-contracting process occurs in the context of a substantial overall reduction in allowed sulfur dioxide emissions. Carlson et al. (1998) estimate that allowance trading in the Acid Rain Program may achieve annual cost savings of $700 million to $800 million over what could be expected from a command and control program with a uniform emission-rate standard.

Optimists have had their positions supported by the failure of the *Club of Rome* predictions regarding the exhaustion of many important nonrenewable resources. In the publication *Limits to Growth* (Meadows et al. 1972), the Club of Rome analysts applied an exponential function for resource consumption to the known reserves of various energy and mineral resources. These analysts arrived at the conclusion that resources such as copper, gold, lead, mercury, natural gas, petroleum, silver, tin, and zinc would all be fully depleted by the year 2000. Petroleum provides about 40 percent of the world's energy, and the prospect that we were going to run out brought substantial attention to the Club of Rome. In fact, none of these predictions came true. One factor that was not addressed in its analysis was the prospect of exploration and discovery of new reserves. For example, the world's proven petroleum reserves nearly doubled between the time of its analysis and 1994, and estimates of world recoverable reserves increased from 600 billion barrels in 1940 to as much as 2,300 billion in 1995 (Campbell 1995). The 1973 OPEC (Organization of Petroleum Exporting Countries) oil embargo resulted in higher prices, which in turn spurred exploration and development of new reserves. Another factor is technological progress that lowers the cost of extraction and so tends to increase reserves. A third factor is the ability to substitute more abundant resources for those that become extremely scarce and expensive. These issues are discussed in greater detail in chapter 5.

Another reason for optimism is that existing environmental regulations in the United States appear not to have diminished the international competitiveness of U.S. manufacturing. As Jaffe et al. (1995) point out, "the conventional wisdom is that environmental regulations impose significant costs, slow productivity growth, and thereby hinder the ability of U.S. firms to compete in international markets" (p. 133). In their comprehensive analysis of the impact of environmental regulations on U.S. manufacturing competitiveness, Jaffe et al. found *relatively little evidence to support the hypothesis that environmental regulations have had a large adverse effect on the competitiveness of U.S. manufacturing (as measured by net exports, overall trade flows, and plant location decisions).* They concluded that "[i]nternational differences in environmental regulatory stringency pose insufficient threats to U.S. industrial competitiveness to justify substantial cutbacks in domestic regulations" (p. 159). These findings are consistent with earlier studies. For example, research by Tobey (1990) found no statistically significant difference in the sensitivity of exports to environmental regulation when comparing industries subject to heavy relative to light environmental regulation, which suggests that the burden of environmental regulation does not significantly impair export performance.

Finally, while there have been localized job losses, the evidence generally suggests that there is little to no aggregate trade-off between jobs and environmental protection. It has been argued that environmental protection measures have led to widespread shutdown of manufacturing plants, encouraged the flight of U.S. manufacturing overseas, and reduced domestic investment in new jobs by hampering productivity growth. In fact, the aggregate data suggest that environmental regulations have not been a major source of aggregate job losses. The U.S. Department of Labor has compiled information on layoffs in which employers are asked to list the primary cause of layoffs. During the period from 1990 to 2000, for example, employers blamed environmental regulations as the leading cause of mass layoffs in less than 0.12 percent of all mass layoffs nationwide (Bureau of Labor Statistics Internet site). In terms of plant locations to so-called pollution havens overseas, Koechlin (1992) found that market size, wages, taxes, political stability, access to European markets, and distance from the United States are the determining factors in decisions by American firms to build facilities in other countries. Nearly 80 percent of U.S. manufacturing investments abroad in 1992 were made in other highly developed countries with relatively strict environmental laws. Grossman and Krueger (1991) found that most plant relocations to *maquiladora* areas of Mexico were motivated by labor cost savings rather than by avoidance of U.S. environmental regulations (labor-intensive firms rather than heavily regulated firms tended to be the ones relocating). Porter (1991) found that those nations with the strictest environmental laws also tended to have the highest rates of economic growth and job creation. Cropper and Oates (1992) found that existing domestic environmental regulations do not appear to have had significant effects on patterns of international trade. Barbera and McConnell (1990) address the question of reduced productivity growth, and they report that no more than 10 to 30 percent of the productivity decline experienced in five industries with the heaviest environmental regulatory burden can be accounted for by environmental regulation. Presumably, the impact has been even lower in less-regulated industries. There is evidence, however, that plant location decisions and job growth across various states within the United States are influenced by the relative stringency of state-level regulation (List and Co 2000; List and Kunce 2000).

As a final point, it is interesting to note that the timber-related jobs lost in the Pacific Northwest—due in part to enhanced forest protection for wilderness-dependent species such as the northern spotted owl—have been more than offset by diversified, often better-paying jobs in areas such as high-technology manufacturing. In fact, despite a considerable reduction in logging activity, the region's employment and income growth exceeded the U.S. national average by approximately a factor of two between 1988 and 1994. As Power (1995) observed, a key factor driving the Pacific Northwest's vibrant economy is the region's attractive social and natural environment. In this sense, environmental protection is a form of investment in the region's economic future.

Reasons for Concern

Although there have been many notable environmental success stories in the United States and elsewhere, there are also many reasons for concern. One reason for concern is the potential for catastrophic change in the global climate because the increased burning of fossil fuels creates greenhouse gases that trap heat and may warm Earth's biosphere. As described in much greater detail in chapter 10, possible scenarios include rising sea levels and inundation of populous low-lying areas such as the Ganges and Nile deltas, and desertification of vital cereal grain-producing areas, both of which would result in mass hunger and dislocation as well as a more rapid loss of biodiversity. Some degree of action on carbon dioxide emissions is justified as a type of insurance premium in the context of uncertain but potentially large future impacts. Yet while the benefits of controlling greenhouse gas emissions remain uncertain, diffuse, international in scope, and cast in the future, the costs of such control are easier to calculate, threaten our lifestyles, and are cast in the present, which makes it politically difficult to enact meaningful greenhouse gas control policy.

Another reason for concern is the continued growth of human population and resulting impacts on the necessary habitats of many of the world's species of animals and plants. Loss of biodiversity is a moral and ethical issue to some, but also has negative impacts on the development of new medicines and on ecosystem resilience, both of which can adversely affect human welfare. Though there is substantial disagreement as to the human carrying capacity of Earth, it is clear that the current pattern of growth and expanding human activity is quickly deteriorating the integrity of the world's remaining temperate zone wilderness areas, coral reefs and other marine ecosystems, and tropical rain forests. Population growth and increases in overall global consumption undermine the gains in resource efficiencies in production. People in developing countries would like to have access to the industrial lifestyle of people in developed countries, with the implication being a staggering increase in future global consumption of energy, the cheapest of which is pollution-intensive coal and oil.

Finally, many of the world's environmental and natural resources problems are linked to failures of democratic process and empowerment, disproportionate consumption of resources by the rich, and large numbers of very poor people living in fragile environments. As related in greater detail in chapter 12, the wealthiest 20 percent of the world's people receive 85 percent of the world's income, while the poorest 20 percent receive only 1.4 percent (UNDP 1994). This gap has doubled since 1960. Two-thirds of the world's people live on the equivalent of $2 or less each day, and recent economic growth has not reduced this proportion. Very poor regions and countries are the least resilient to stresses and shocks such as prolonged droughts and political instabilities. With few options, the response to these shocks often leads to intensified deforestation, farming on unstable slopes and nutrient-poor rain forest soils, and other forms of resource degradation as well as migration to crowded and highly polluted urban areas. Poor and politically disenfranchised people are subjected to massive environmental degradation in places such as Ogoniland in Nigeria. Two-thirds of the world's illiterate people are women, and there is a strong inverse relationship between women's educational attainment and fertility. Yet, worldwide female illiteracy rates actually increased from 58 percent in 1960 to 66 percent in 1985.

What inference can we draw from these examples of policy successes and areas of concern? Clearly we have made some progress, and environmental and natural resources economics has played a role in some of those successes. However, we are also faced with enormous challenges worthy of our best efforts.

Overview

This book has three main parts. The first is about developing an understanding of basic theoretical issues and fundamentals in environmental and natural resources economics. We will begin this part by discussing value systems and their role in economic decisions. We will learn that, indeed, there is an unavoidable subjective element to how we rank the choices that are available to us with regard to the environment. Yet while we can disagree about valuations, economists agree that markets do not function properly when firms can shift costs by polluting, which provides a possible justification for government regulation of the marketplace. This is an important point, and we shall develop a rather detailed understanding of the conditions under which markets "fail" and how market failure provides an economic justification for society as a collectivity to intervene in the market process. This first portion of the book ends with an introduction to the economics of natural resources, with some emphasis placed on common-pool resources and the debate over growth and increasing resource scarcity.

The second part of this textbook addresses policy. We will start out discussing methods, merits, and limitations of benefit/cost analysis, which is a common economic technique used in policy analysis. The next chapter in this part discusses the political economy of environmental and natural resources policy-making, followed by a chapter on the economics of compliance with environmental and natural resources regulations, focusing on the role of monitoring and sanctioning in providing incentive to comply. We then turn to the economics of incentive regulation. Economists have been refining their models for efficient regulation to introduce incentives for polluters, and the EPA and other government agencies have increasingly been experimenting with these incentive regulatory schemes. The policy part ends with an analysis of global-warming policy, a case study in the challenge of policy-making in the context of scientific uncertainty, irreversibilities, and an international scope. Global warming is also an area in which policymakers must acknowledge that people over a very distant horizon will likely be affected, and provides a bridge to the material on sustainability in the last portion of the book.

The economics of a sustainable society, the topic of Part III of the book, is about sustaining economic efficiency, environmental integrity, and elements of social justice over a long-term period. After a brief introduction, the material begins with a chapter covering the linkages between poverty, growth in population and economic activity, and the integrity of environmental and resource systems. Once we develop a basic understanding of how social, economic, and ecological factors are linked, we will then discuss policies that are better targeted at improving and sustaining the quality of people's lives over time. One example is the movement for sustainable development, which is the subject of another chapter. Making sustainable development operational calls for methods and strategies for sustainable production and consumption. The final chapter investigates concepts, methods, and case studies related to sustainable local communities. Special attention will be paid to linkages between local people and the local natural resource systems on which they depend.

It is hoped that this book fosters not only a better understanding of economics and the environment but also an appreciation of the challenges and rewards of forming environmental and resource policy in a diverse society.

Summary

- Environmental economics focuses attention on pollution problems and on policies to resolve them. Natural resources economics studies the problems of governing common-pool natural resources, of dynamically optimal rates of resource extraction, and of resource markets. The sustainability movement is concerned with maintaining or enhancing ecological integrity, economic vitality, and democratic political and social institutions over time.
- Economics is the study of how scarce resources are allocated among competing uses. Something is said to be scarce when, at a zero price, more is wanted than is available. Something scarce can be allocated to a variety of different uses. When one use is chosen, the opportunity cost of that choice is the value of the next best alternative, which was sacrificed. A rational choice from among competing options is anticipated to yield benefits that exceed the opportunity cost.

- There are a number of reasons for optimism. Environmental policies have generated substantial improvements in air quality in the United States, and production methods are becoming cleaner. There does not seem to be much support for the argument that environmental protection results in overall job loss in the United States. While production facilities have moved from the United States to Mexico and other developing countries, the primary motive appears to be lower-cost labor rather than the cost savings from pollution havens.
- Yet there are important areas of concern, including population growth, global warming, and loss of biodiversity.

Review Questions and Problems

1. You are an investigative reporter covering the issue of a trade-off between jobs and the environment.

Your assignment is to write a 500-word column that provides:

a. A brief overview and description of the concept of a jobs versus environment trade-off
b. An explanation of situations in which environmental protection has resulted in job losses
c. A summary of the evidence for a jobs versus environment trade-off using national-level (macroeconomic) data (see discussion in the text in this chapter)
d. A conclusion that summarizes the jobs versus environment story and perhaps strays a bit into the political economy of who benefits from this persistent myth

2. Price is a simple indicator of value for things traded in markets. Yet if the economic problem also applies to something like a wilderness area, which has no price to indicate value, then how are we to assign value to it?

a. Think of some specific indicators of the monetary value of a wilderness area that an analyst could measure.
b. What are some monetary indicators of the opportunity cost of wilderness preservation?
c. If we were to make a decision regarding how to manage the land area under analysis based on the information you provided in (a) and (b) above, what other elements of value might be omitted and thus not be reflected in the policy decision?

Internet Links

Economic Report of the President (http://w3.access.gpo.gov/eop/): Extensive source of up-to-date U.S. economic information.

Environmental Protection Agency's Economy and Environment Program (http://www.epa.gov/oppe/eaed/eedhmpg.htm): The U.S. EPA's Economy and Environment Program carries out research and analyses of the interactions and relationships between the economy and environmental pollution control as well as other aspects of environmental economics. This includes determining the economic benefits and costs of pollution control, the use of economic incentives for pollution control, and the size, composition, and impacts of the pollution control industry.

Federal Reserve Economic Data (http://www.stls.frb.org/fred/index.html): Comprehensive source of U.S. economic data.

FedStats (http://www.fedstats.gov/map.html): This site provides easy access to the full range of statistics and information produced by over seventy agencies of the federal government.

Food and Agriculture Organization (http://www.fao.org/): A UN organization offering extensive research reports and databases having to do with agriculture, economics, fisheries, forestry, human nutrition, and sustainable development.

Major Schools of Economic Thought (http://www.frbsf.org/econedu/unfrmd.great/greatschls.html): An easy-to-read summary produced by the Federal Reserve Bank of San Francisco.

Textbook Internet Site (http://www.humboldt.edu/~envecon): Includes lecture outlines, extensive annotated Internet links, interactive Excel-based simulations, audio clips, lecture outlines, interactive quizzes, and much more.

World Resources Institute (http://www.wri.org/): The World Resources Institute provides information, ideas, and solutions to global environmental problems. The organization publishes the authoritative biennial *World Resources*.

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2

Value Systems and Economic Systems

Introduction

Economics is concerned with the problem of allocating scarce resources among competing uses. When something is scarce, allocating it to one use means we forgo the opportunity for another use, creating an opportunity cost. An allocation is good when it generates net benefits that exceed the opportunity cost. Thus, at the most basic level, economics is about understanding opportunity costs. All human societies are confronted with this fundamental problem. Throughout time and around the globe, societies have been motivated by widely different social and philosophical value systems for determining benefits and costs and so have had different answers to the question of what a good way to allocate things might be. As a consequence, we have observed many different kinds of economies. Understanding economic systems provides insight into otherwise inexplicable aspects of our lives and the choices that we make.

In this chapter we will investigate several fundamental questions related to human values and economic systems. We will first consider the basis for distinguishing a good economy from a bad one, or a good allocation choice from a bad one. A response to this question might be that a good economy is more efficient than a bad one, producing things of value with a minimum of waste, and allocating resources to their highest-valued use, and indeed few would deny that efficiency is a central element of a good economy. But the judgment of what constitutes a wasteful resource allocation, and how we determine highest-valued use, depends critically on the value system of the judge. Even more fundamental is the question of whether an action (for example, policy protecting old-growth forest) is to be judged on its intrinsic rightness or based on the measurable benefits and costs that might result from the allocation. We will also consider the problem of determining the proper balance between individual self-interest and the common good. We will conclude the discussion of value systems by presenting contrasting perspectives on the basis for and the merits of private property rights systems.

We will then turn to a discussion of some fundamental issues associated with economic systems and methods. One of these has to do with different methods of economic analysis. One branch of economic analysis is based on the Western scientific method of describing, explaining, and predicting observable empirical phenomena. A set of “best methods” for describing observable phenomena has evolved that is generally accepted by the community of economic practitioners, and analyses that properly follow these best methods yield findings that generate little in the way of disagreement. For example, the hypothesis that a per-unit tax on corporations will result in a short-run increase in price and reduction in volume of trade can be evaluated empirically, and this form of positive analysis can also tell us the amount by which price rises and volume of trade declines. Another branch of economic analysis proposes a set of “best choices” based on particular normative systems of value. Thus, a profit-maximizing corporation can be advised of a system of compensation designed to best align the incentives of its employees with the maximization of profit for the firm. Or a government can be advised as to the best use of an old-growth forest based on the utilitarian value system of benefit/cost analysis. It is important to distinguish these forms of analysis; while the former yields something we can think of as fact, the latter naturally generates disagreements among economists who articulate arguments derived from widely different systems of value.

We will conclude the discussion of economic systems by describing the fundamental choices required of all societies by the condition of scarcity, regardless of the value system or criteria for efficiency that are employed. These choices are: what should we allocate resources to produce (e.g., produce board feet of timber or wildlife habitat), by what method should we produce (i.e., choice of engineering or management system), and who receives what is produced? The fundamental issues discussed in this chapter provide a broad foundation for the analysis of markets, market failure, and social policy that is to follow in the remainder of the book.

Fundamentals of Ethical Systems

Society is frequently confronted with policy decisions that must be made because of scarcity. Examples include the allocation of budget monies and the management of public land, water, and wildlife. These policy decisions affect both human and nonhuman communities. Because of scarcity, any choice made by policymakers will have an opportunity cost. What are the values that will be used to rank policy alternatives? From an economic point of view, a decision is good when it generates net value that exceeds the opportunity cost. Yet different value systems will lead to a different ranking of alternatives and so will provide different answers to the question of which course of action is best. As you can see, in order to make good economic decisions we need value systems to rank alternatives. When individuals make choices in the context of scarcity they are guided by their own values and preferences, as well as by those of their culture. To make public policy decisions that serve the interests of the public, however, the economic and political aspects of policymaking must embody society's shared or dominant values, or aggregate individual values and preferences. This is one reason why social institutions, such as those that provide the structure for political and economic choices and interactions, embody the shared or dominant values of the societies from which they evolve.

Ethics is a branch of philosophy that is concerned with moral duty and ideal human character. Morals are defined to be principles of right and wrong, of good and bad. Ethical systems either describe particular shared values, or provide a method for arriving at an aggregation of individual values and preferences. Different ethical systems lead to different economic choices. There are two traditional classes of ethics—deontological and teleological—which are described below.

Deontological Ethics

Ethical systems in the deontological tradition develop theories of action based on duty or moral obligation. Under this system, an action is judged by its intrinsic rightness and not by the extent to which it serves as an instrumentality in furthering one's goals or aspirations. Immanuel Kant, one of the best-known proponents of this ethical system, argued in *Foundations of the Metaphysics of Morals* (1785) that there are two types of *imperatives* or rules that command or direct our proper behavior: "All imperatives command either hypothetically or categorically. The former presents the practical necessity of a possible action as a means of achieving something else which one desires (or which one may possibly desire). The categorical imperative would be one which presented an action as of itself objectively necessary, without regard to any other end" (p. 96).

As O'Brien (1996) points out, a hypothetical imperative commences with a statement such as "If we want to limit acid rain, we ought to reduce emissions of sulfur dioxide and nitrogen oxides." Kant would refer to this as a practical reason for taking an act. Kant's major contribution to the development of deontological ethics is the notion of a *categorical imperative*. Unlike a hypothetical imperative that appeals to reason, a categorical imperative asserts that a particular action is intrinsically necessary without regard to the outcome or ends that might possibly derive from the act. Thus, from the perspective of a categorical imperative, one could argue that a person should never treat another person as a mere means to an end or a goal. The basis for ethical behavior, according to Kant, was for autonomous people to freely submit themselves to the same rules that they would prescribe for others, in which case individual autonomy would lead to cooperative harmony.

Perhaps one of the best-known "neo-Kantians" is John Rawls and his theory of justice as fairness. *Justice* here means the principle of rightness of action. Rawls (1971) conceived of justice as arising from a state of ignorance. In particular, Rawls proposed the following thought experiment. If people could select some principle of justice (e.g., that society has the duty of assisting the less fortunate) before they were aware of their own status and position, then under this "veil of ignorance" people would not be biased toward justice systems that favor their particular situation. In the "original position" that exists prior to the revelation of differences in status and position, people would naturally agree on the intrinsic value of a justice system that favors the least advantaged in society. Rawlsian justice is deontological because the ethics of justice determine rightness of action as a categorical imperative. The link between Kant and Rawls can be seen in the following quote from Kant's *Foundations:* "There is, therefore, only one categorical imperative. It is: Act only according to the maxim by which you can at the same time will [i.e., make happen] that it should become a universal law" (p. 101).

Both Aldo Leopold's land ethic and Bill Devall's conception of *ecosophy*, or earth wisdom, can be considered examples of deontological ethical systems, calling for ecosystem protection as a categorical imperative. The deep-ecology movement promotes ecosophy by way of becoming grounded "through fuller experience of our connection to earth" (Devall and Sessions 1985). In 1984, Naess and Sessions articulated a set of deep-ecology principles (Devall 1988):

- The well-being and flourishing of human and nonhuman life on Earth have value in themselves [intrinsic value]. These values are independent of the usefulness of the nonhuman world for human purposes.
- Richness and diversity of life-forms contribute to the realization of these values and are also values in themselves.
- Humans have no right to reduce this richness and diversity except to satisfy vital needs.

- The flourishing of human life and cultures is compatible with a substantial decrease of the human population. The flourishing of nonhuman life requires such a decrease.
- Present human interference with the nonhuman world is excessive, and the situation is rapidly worsening.
- Policies must therefore be changed. The changes in policies affect basic economic, technological, and ideological structures. The resulting state of affairs will be deeply different from the present.
- The ideological change is mainly that of appreciating life quality (dwelling in situations of inherent worth) rather than adhering to an increasingly higher [material] standard of living. There will be a profound awareness of the difference between big and great.
- Those who subscribe to the foregoing points have an obligation directly or indirectly to participate in the attempt to implement the necessary changes.

We have seen that deontological ethical systems lead to expressions of categorical imperatives that prescribe certain necessary actions. Deontological ethics can serve to guide social policy for those circumstances for which members of society share the same values. In diverse societies, however, policies based on one group's system of intrinsic value may be oppressive to those holding different values. If a community or society lacks common ground on a set of deontological principles, then an alternative that is investigated below would be to aggregate individual preferences.

Teleological Ethics

Telos is a Greek term for "end" or "purpose." Under teleological systems of ethics, an action is judged not by its intrinsic value but by the extent to which the action has instrumental value in providing advancement toward a desirable end. If an action is instrumental in yielding a desirable end, then generally the action itself is ethical. Thus, the ethical focus is on goals rather than actions. Central to teleological systems is the notion of *consequentialism*: the moral worth of actions or practices is determined solely by the consequences of the actions or the practices (Beauchamp and Bowie 1979). This ethical system was advocated by Aristotle and later by religious philosophers exploring natural-law ethics and by utilitarian philosophers such as David Hume, Jeremy Bentham, and John Stuart Mill. To avoid the obvious criticism that under teleological ethics "the end justifies the means," Aristotle argued that one must instead look at each individual action and justify it in terms of its own goal. Of the various teleological ethical traditions, the one most relevant to environmental and natural resources economics is *utilitarianism.*

Under this system of teleological ethics, the merits of an action (e.g., a social policy) are evaluated by considering the total benefits (utility) and the total costs (disutility) created by the action for human society. Under *act utilitarianism* a social rule is followed if, after adding up the utility and the disutility the rule will cause for all members of society, the net utility is positive. Thus, this rule is sometimes imprecisely characterized as providing "the greatest good for the greatest number." This isn't always true, however, because it is possible that the utilitarian-ethical policy will generate large benefits to a few and very small costs to many. Another problem with utilitarianism is that it can be used to impose the tyranny of the majority. Act utilitarianism can therefore be used to justify throwing a virgin into a volcano if it is believed that such an act will save a village from the ravages of an eruption. Utilitarian ethics is teleological because the merit of a rule is judged by its effect, or ends, rather than by the intrinsic rightness of the act itself independent of any possible outcome or end.

Utilitarian principles are prominent in contemporary policy analysis. In diverse societies where people cannot agree on the intrinsic merits of certain actions, as is required by systems of deontological ethics, utilitarianism offers an alternative that provides for the weighing of aggregate policy impacts across diverse elements of society.

A Closer Look at Utilitarianism

Much of the traditional economic perspective on social policy has utilitarianism as its normative base, perhaps because economists prefer to avoid commitment to a particular deontological system and the intrinsic values that it obtains. Benefit/cost analysis is a common method of policy analysis that derives from a utilitarian ethical system. Hence, it is worthwhile to consider utilitarianism in greater detail. Utilitarianism as a means of social progress in economics was perhaps best articulated by Jeremy Bentham, a younger contemporary of Adam Smith (who professed the "natural utilitarianism" of decentralized market processes). As Beauchamp and Bowie (1979) point out, Bentham was particularly dissatisfied with the legal theories of William Blackstone, which served to justify the British legal system. In particular, Bentham believed that the British system of ranking crimes was wrong because it was based on an "abstract moral theory" rather than on the unhappiness, misery, or disutility a crime caused to other members of society. Thus, in Bentham's view the punishments prescribed by law should be proportionate to the disutility created by the crime and not based on notions of intrinsic rightness or morality. In his book *Principles of Morals and Legislation* (1790), Bentham described utility as the principle that approves or disapproves of actions according to their tendency to increase or decrease an individual's pleasure. Bentham was a hedonist and so believed that pleasure is the only intrinsic good or end against which acts are to be evaluated. As W.H. Auden (1962) observed, "Pleasure is by no means an infallible critical guide, but it is the least fallible."

While Adam Smith argued in *Wealth of Nations* that in many commercial contexts the social welfare was best met through the "invisible hand" of the market, Bentham identified conditions in which society needed to act collectively to resolve social problems such as disease, sanitary water supplies, and so forth. These were rather radical ideas at the time. Bentham's notion of utilitarianism is conceptually very simple. Suppose that each person in society is affected by a set of possible policy options. For each option, the utility gains to those benefiting from the policy, as well as the disutility (utility losses) to those being harmed by the policy, are to be added up to arrive at net social utility. The utilitarian–ethical policy is the one that maximizes net social utility relative to all the other options under consideration. Bentham therefore conceived of what we now call "cardinal utility," which means that pain and pleasure can be reduced to a positive or a negative number for each person, and the social engineer can measure these numbers and simply add them up. Therefore, one person's unhappiness with a policy yields a utility number that can be directly compared to the utility number for someone else's happiness. As you can see, the concept of cardinal utility is based on the notion that utility is objectively measurable and comparable across individuals. From a mathematical perspective, social utility is computed using something called a *social utility function.* Utilitarian policy analysis calls for the computation of net social utility for each of the new policies under consideration, and the utilitarian–ethical policy option is the one (if any) that generates the largest increase in net social utility relative to the status quo. Note that status quo means "the current way of doing things."

Amartya Sen (1987) has reduced utilitarianism to three elementary factors:

- *Welfarism:* The "goodness" of a proposed rule depends on utility information. In other words, the goodness of a proposed rule is determined by the utility or disutility that it creates among members of society.
- *Sum ranking:* The utility information regarding any proposed rule is assessed by looking only at the sum total of all the individual utilities associated with the rule. In other words, in evaluating a proposed rule, utilitarianism requires that we add up the utilities and the disutilities that the rule creates among all members of society.

- *Consequentialism:* Every rule choice must ultimately be evaluated by the goodness of the consequent state of affairs (the "ends" it moves us toward). In other words, under utilitarianism the ethical policy is the one that generates policy outcomes ("ends") that lead to the largest net social utility.

Utilitarianism also allows for the evaluation of efficiency. Two different efficiency criteria are commonly used by economists for evaluating social policy.

The *Pareto efficiency criterion* is named after Vilfredo Pareto, an early economist, and it imposes a stringent requirement for any change from the status quo. As an example, suppose there are five policy alternatives to the status quo being considered. To determine whether any of them are Pareto efficient, we must evaluate the impacts of each policy alternative on every member of society. If a policy alternative makes any member of society worse off than under the status quo, then that policy alternative is eliminated from further consideration. Continuing our example, suppose that four of the five policy alternatives are eliminated because they make one or more members of society worse off relative to the status quo. Thus, there is only one policy alternative that makes some people better off and nobody worse off than under the status quo. This policy alternative is said to be Pareto-efficient relative to the status quo.

Unfortunately, few real-world policy alternatives can pass the Pareto criterion because it is so difficult to assure that no one is made worse off than under the status quo. Because of this, economists consider the Pareto efficiency criterion to be biased toward preserving the status quo. This can create a serious social conflict when many in society see the status quo as being unethical from a deontological perspective. A historically important example is slavery in the United States. Slavery was widely seen in the North as being unethical from a deontological perspective, but a policy alternative of ending slavery would make slave owners worse off than under the status quo, and thus would have failed the Pareto efficiency criterion. These arguments may help to explain why the Pareto efficiency criterion is rarely used in policy analysis.

An alternative approach that is more widely used is simply to rank policy alternatives based on net social utility, as originally conceived by the utilitarians, and to do away with the requirement that no one be made worse off relative to the status quo. This less rigorous efficiency criterion was proposed by economists Nickolas Kaldor (1939) and John Hicks (1939). Going back to our original example of five policy alternatives to the status quo, we would no longer eliminate four of the five because they made some members of society worse off. Instead, according to the *Kaldor–Hicks efficiency criterion,* we must compute net social utility (adding up the gains and the losses for each member of society) for each policy alternative to the status quo. The policy alternative that generates the largest gain in net social utility is the Kaldor–Hicks-efficient policy alternative. This also corresponds with the utilitarian–ethical policy alternative.

The Kaldor–Hicks efficiency criterion is sometimes referred to as being potentially Pareto efficient because the potential exists for those made better off under a policy change to compensate those made worse off and thus share the net benefits with all members of society. We actually see crude attempts at this sort of compensation scheme in certain social policies that make some people worse off. For example, consider the Clinton administration's preservation scheme for the northern spotted owl, which limited the harvest of old-growth trees and thus made some local timber-dependent communities in the Pacific Northwest worse off. The Northwest Economic Adjustment Initiative, an element of the Northwest Forest Plan, allocated $1.2 billion in general tax dollars to retrain dislocated workers, assist local businesses, diversify the economy of the region, enhance community infrastructure and technical capacity, and restore watersheds and create short-term jobs through a "Jobs in the Woods" program. If those made worse off under a policy alternative that is Kaldor–Hicks efficient could be fully compensated, then the policy alternative would also satisfy the Pareto efficiency criterion.

As you may have guessed, it is not possible to directly compare one person's level of utility to that of another and, thus, to construct a true social utility function as envisioned by the classical utilitarians. Because of this, economists and others who wish to rank policies based on a utilitarian ethic usually approximate utility and disutility with estimates of monetary benefits and costs. The implicit assumption is that since a dollar is a measure of value in markets, the utility that one person can derive from a dollar (in terms of the available goods and services that can be purchased with the dollar) is the same as that of another. Though this is a convenient assumption that allows economists to conduct benefit/cost analysis, there is no reason to believe it is true. In fact, many economists believe that the utility that a person derives from the purchasing power of a dollar declines as the person's income rises. In other words a dollar creates less of a utility gain to a billionaire than to a homeless mother with a hungry child. We will discuss these and other issues related to benefit/cost analysis in greater detail in chapter 6.

The fundamental economic problem of allocating scarce resources among competing ends exists regardless of whether society subscribes to a deontological or a teleological system of ethics. The dilemma of endangered species protection offers a good illustrative example. The existence of an endangered species is subject to scarcity; this is because both the protection and restoration of a species and the habitat it requires involve opportunity costs associated with development activities and alternative uses of protection and restoration funds. In a society that views the existence of a species as being of intrinsic value (deontological ethics), the categorical imperative calls for actions that make at least minimal provision for habitat preservation regardless of cost. The fact that the species is of intrinsic value places its habitat above the value of human appropriation, unless perhaps the development is required to prevent loss of human life (a potentially higher intrinsic value). In a society that views the existence of a species as being subject to a utilitarian calculus, the allocation problem is resolved by benefit/cost analysis, and the opportunity cost is the value of whichever option (species protection or development) yields the next highest net benefits. The difference in cases is not whether an economic problem exists but how that problem is to be resolved.

Self-Interest, the Common Good, and Social Order

One of the central dilemmas that all societies must confront is how to maintain social order and thus balance the sometimes conflicting imperatives of self-interest and the common good. Hobbes (1651), for example, argued that unless there was a "common power" to keep people "in awe," the natural state of human society is one of war and conflict:

> Hereby it is manifest that during the time men live without a common power to keep them all in awe, they are in that condition which is called war; and such a war as is of every man against every man. Whatsoever therefore is consequent to a time of war, where every man is enemy to every man, the same consequent to the time wherein men live without other security than what their own strength and their own invention shall furnish them withal. In such condition there is no place for industry, because the fruit thereof is uncertain: and consequently no culture of the earth; no navigation, nor use of the commodities that may be imported by sea; no commodious building; no instruments of moving and removing such things as require much force; no knowledge of the face of the earth; no account of time; no arts; no letters; no society; and which is worst of all, continual fear, and danger of violent death; and the life of man, solitary, poor, nasty, brutish, and short.

If we assume for a moment that Hobbes is right, then what is this common power that keeps people in awe and prevents violent and destructive conflict? Some argue that this is the role of religion. As Fukuyama (1999) argues, in Western society, "Christianity first established the principle of the universality of human dignity, a principle that was brought down from the heavens and turned into a secular doctrine of universal human equality by the Enlightenment" (p. 80). Others, such as sociologist Max Weber, argue that social order in an industrialized society must come from the rational bureaucracy of a strong centralized government.

It should be pointed out, however, that self-interest and the common good are not always in conflict, and that war and conflict may not be our natural state. As you will learn in greater detail in chapter 3, Adam Smith argued that self-interested interaction in a well-functioning competitive market will yield outcomes that are consistent with the common good. Moreover, it is argued that many small preindustrial communities around the world were self-organizing and thus did not need external religious or bureaucratic structures.

In the case of social order in modern industrial society, Fukuyama observes:

> The modern liberal state was premised on the notion that in the interests of political peace, government would not take sides among the differing moral claims made by religion and traditional culture. Church and State were to be kept separate; there would be pluralism in opinions about the most important moral and ethical questions, concerning the ultimate ends or the nature of the good. Tolerance would become the cardinal virtue; in place of moral consensus would be a transparent framework of law and institutions that produced political order. Such a political system did not require that people be particularly virtuous; they need only be rational and follow the law in their own self-interest. (p. 58)

This transparent framework of law and institutions must be supplemented by at least a minimum level of *social capital*. As we shall discuss in greater detail in chapter 11, "social capital," according to Putnam (1993), refers to the features of social organization including networks, norms, and trust that facilitate coordination and cooperation for mutual benefit. Putnam recognized that in regions with high social capital, residents are engaged in public issues, trust one another, make and keep commitments, engage in reciprocity, and obey laws. Social and political institutions tend to be organized horizontally, rather than hierarchically, and solidarity, civic participation, and integrity all tend to be highly valued. Putnam has observed that while social capital seems to be a precondition for economic development and effective government, it tends to be underprovided by private agents. Thus, the culture of individualism that is reinforced by the modern liberal state undermines the shared values and the contribution to social capital that creates social order.

Along the same lines, a number of studies have indicated that classroom exposure to the model of the self-interested maximizer in economics affects student and faculty attitudes toward voluntary contributions. Frank et al. (1993) analyzed the responses to a questionnaire from 576 college and university professors from a variety of disciplines. Frank and his colleagues found that economists were among the least generous of the group. For example, 9.3 percent of the economics professors gave no money to charity, relative to a range of between 1.1 and 4.2 percent in other surveyed fields. Additional support is offered by the work of Marwell and Ames (1981). In a series of laboratory experiments, Marwell and Ames studied voluntary contributions in a simulated environment in which the contributions are used to create public goods that benefit the group as a whole. Economics students were found to donate less than half as much as students from other disciplines. Finally, Carter and Irons (1991) studied the "ultimatum game" in which one person decides how to share a pool of money with another, and the other person can either accept the allocation or throw away the entire pool of money. Economics majors were far more likely to allocate all but a cent or two to themselves relative to nonmajors, who more commonly split the pool of money equally. These findings are also consistent with those of Kahneman et al. (1986). These studies offer some remarkable evidence that exposure to the model of the self-interested maximizer does indeed encourage self-interested behavior outside the confines of markets where such behavior is most likely to be appropriate.

Private Property

So far we have discussed different conceptions of ethics, which provide a guide to our relations with others, and of social capital, which serves as the foundation for social order and helps resolve the conflict between self-interest and the common good. Western notions of private property and its origins also provide useful insights into our relationship with one another and with the natural world. The origin and implications of private property rights can be found in the liberal society described by John Locke, and the civil society of Jean-Jacques Rousseau and other Enlightenment philosophers. Let's take a moment to consider these two perspectives on the origin and implications of private property.

Locke and the Liberal Society

The liberal society is articulated in Locke's *Two Treatises on Government* (1690). Locke sees the fundamental goal of society as providing opportunities for people to exercise their talent and effort in the creation of valuable personal property and the well-being that derives from this property. In his conception of private property rights, Locke's Christian cosmology provides as self-evident truth that God gave earth to man in common. He then sets out to explain that God also gave man the capacity and the imperative to make the best use of God's gift in satisfying man's "support and comfort." Completing the construct, Locke concludes:

> Every man has a Property in his own Person. . . . The Labor of his Body, and the Work of his Hands, we may say, are properly his. Whatsoever then he removes out of the State that Nature hath provided, and left it in, he hath mixed his Labor with, and joined to it something that is his own, and thereby makes it his Property. It being by him removed from the common state nature placed it in, hath by this Labor something annexed to it, that excluded the common right of other Men. . . . [Y]et there are still *greatest Tracts of Ground* to be found, which (the Inhabitants thereof not having joyned with the rest of Mankind, in the consent of Use of their common Money) *lie wasts*, and are more than the People, who dwell on it, do, or can make use of, and so still lie in common. (pp. 77, 84)

It is interesting to see some of the concepts of what later came to be the U.S. Homestead Act of 1862 articulated in the writings of Locke, such as the requirement in the Homestead Act for "actual settlement and cultivation" in order to patent a claim on otherwise "unappropriated" public land. We also gain insight into our cultural past by reading the argument Locke gives for denying aboriginal people a private property right, which seemingly provided a justification for the taking of aboriginal lands.

Rousseau and the Civil Society

In *Discourse on Inequality* (1755), French philosopher Jean-Jacques Rousseau argued that an early golden age of social cooperation, interdependence, and freedom existed prior to the emplacement of private property regimes that underlie the civil society. From Rousseau's perspective, contemporary civil society and the private property rights systems that are its basis alienate people from nature, lead to greater and greater inequality, and ultimately are responsible for wars and other destructive conflicts. The transformation from the early natural state to contemporary civil society occurred as human enlightenment led to the refinement of skills for the modification of nature. Perhaps following Locke, Rousseau saw the introduction of private property as occurring when a person applied his or her skill to create something of value from nature, such as a hut or shelter. Family societies formed around these dwellings and were bound together by mutual attachment and freedom. Specialization and teamwork in hunting and gathering led in turn to abundant leisure time, which could be filled by the development of tools and other conveniences. This is the point at which Rousseau first sees the evils of civil society, as tools and other conveniences "degenerated into real needs, . . . and men were unhappy to lose them without being happy to possess them" (p. 67).

Rousseau goes on to argue that:

> To the poet it is gold and silver, but to the philosopher it is iron and grain that made men civilized and brought on the downfall of the human race. . . . When men were needed for smelting and forging iron, others had to feed them. . . . Since the artisans required food in exchange for their iron, the others finally found means of using iron to increase the amount of food available. . . . The division of land necessarily followed from its cultivation, and once property had been recognized it gave rise to the first rules of justice. . . . It is work alone that gives a farmer title to the produce of the land he has tilled, and consequently to the land itself. . . . If this possession is continued uninterruptedly from year to year, it is easily transformed into ownership. When the ancients, says Grotius, called Ceres "the lawgiver" and gave the name Thesmaphoria to a festival celebrated in her honor, they implied that the division of land had produced a new kind of right: the right of property, different from that which derives from natural law. . . . Things in this state might have remained equal if abilities had been equal. . . . It is thus that natural inequality [skills, effort, etc.] gradually becomes accentuated by inequalities of exchange, and differences among men, developed by differences in circumstances, became more noticeable and more permanent in their efforts, and begin to influence the fate of individuals in the same proportion. (pp. 70–72)

Rank and position in society, according to Rousseau, are gauged by property and power to coerce others. Freedom was lost as people became slaves to the social demands for property, leading to "competition and rivalry on the one hand, opposition of interests on the other, and always the hidden desire to profit at the expense of others. All these evils were the first effect of property, and the inseparable accompaniments of incipient inequality" (pp. 72–73).

Society must balance individual liberty against environmental and community integrity. Where a particular society ends up depends on the evolution of its culture, laws, values, and economic, social, religious, and political institutions. All along the spectrum from communal living to libertarian anarchy there will be economies that are *alike* in that they provide ways of allocating things that are scarce, but which *differ* in how that allocation occurs. Moroever, each ethical system implies its own economic system. Thus, we have Amish and Mennonite communities that have social and religious constraints that limit the scope of market exchange within and outside their communities. Many scarce resources, goods, and services in these communities are allocated in the form of gifts or based on need, and the social structure provides considerable insurance in a nonmarket context. These communities produce much of what they need and so engage in only a limited trade for imports with the greater U.S. economy. In contrast, most American communities have a secular consumer culture and rely much more completely on markets for the exchange of goods and services and for the provision of insurance, and goods and services are allocated based on willingness to pay. Economies of scale and the extensive use of markets to allocate scarce resources, goods, and services imply that these communities tend to specialize in producing a narrow range of products and engage in extensive trade outside the community to meet their needs and desires. These examples illustrate how economic systems and institutions embody a community's dominant values.

On Positive and Normative Economics

So what is the nature of our economy, and what should we do to change it? In responding to these questions, it is useful to consider an illustrative example. Suppose that policymakers are considering taxing products whose production or consumption generates pollution. Two questions that arise are (1) what can we expect to be the observable effects of this tax in the short and long term, and (2) should we do it?

Economics has two methodologically distinct branches that speak to these questions. *Positive economics* is a method of analysis based on the Western scientific tradition of modeling the world and then subjecting these models to empirical test using data from "out there" in the world. A set of best methods for empirical research has evolved that allows for internal and external validation of these models. As a consequence, economists can broadly agree on how good a positive economic model is by how well the data support it. Modeling improves through a process of scientific evolution in which weak and falsified models are sloughed off. Thus, positive economics seeks to explain the observable. Because the real world is hopelessly more complex than we can ever hope to model comprehensively, a positive analyst must focus on what is thought to be the most important elements of the phenomena being studied. The selection process by which researchers determine what is important enough to include in their models and what can be ignored is subject to normative interpretation, deriving in part from the culture and the values of the research community and the role of the researcher in that community.

As an example, positive economic analysis might use empirical methods to estimate the impacts of a pollution tax on electricity prices, electricity consumption, and pollution emissions. But what of the myriad other effects of the tax, the values of which are difficult to measure, compare, and agree on? For example, one might argue that the value of protecting personal liberty exceeds the net benefits of remediating pollution. Another might argue that knowingly allowing a company's pollution to harm people without compensation is unethical to such a degree that pollution should be taxed even if the net benefits of remediating pollution are negative. *Normative economics* is about identifying what a person, a business, or a society should do. Note that a *norm* is defined as a rule or an authoritative standard. Economic policy recommendations are a form of normative analysis, and such an analysis is how economists would try to answer the second question above.

Economic Questions That All Societies Must Answer

Society's dominant values determine how we answer the *three fundamental economic questions:*

- *What* goods and services are produced, including what "services" we derive from natural resources systems (e.g., wilderness or timber)?
- *How* they are produced, involving issues like technology, pollution, and harvest techniques?
- *Who* gets things, involving issues like the extent to which prices or other factors are used to allocate goods and services and whether the rich subsidize the poor?

In the next chapter we will learn about how a pure system of market capitalism answers the three fundamental economic questions.

Summary

- Economics is concerned with finding good ways (often termed "efficient" ways) of allocating things (e.g., goods, services, resources, time, land, air, water) that are scarce.
- How we judge the meaning of *good* or *efficient* depends on our value or ethical system(s).
- There are deontological and teleological systems of ethics, among others, and different specific forms within each of these two categories. Such

ethical systems underlie all we do in economics, because they provide the basis for ranking alternatives and determining opportunity cost.

- We live in a diverse, pluralistic society in which honorable people subscribe to different ethical perspectives and therefore differ in their perception of what fairness and justice means and thus what the relative value of different things might be.
- A fundamental challenge is to forge durable social policy in the context of this diversity.
- Modern, mainstream, Western-style economics has utilitarianism as its normative base. Utilitarianism as a normative underpinning is not *required* of economic systems, however. Economic systems built on natural-law ethical underpinnings were quite common in the Middle Ages in Europe and likely in village economies in many primary societies.
- Social capital forms the foundation for social order and the capacity to resolve conflicts between self-interest and the common good. A culture of self-interested individualism is promoted by market capitalism and democracy, and yet this culture can undermine the structure of social capital.
- Positive economics is concerned with using scientific methods to describe the world around us, whereas normative economics is concerned with articulating what we should do.
- The three fundamental economic questions that all economies must answer are what to produce, how to produce, and for whom to produce.

Review Questions and Problems

1. The Endangered Species Act calls for the protection and recovery of listed species independent of cost. It has been argued that the act needs to be modified to incorporate benefit/cost analysis.
   a. Describe the ethical conflict at the heart of this debate.
   b. Is benefit/cost testing of species protection necessary for the act to be economically rational, or is this an argument based in utilitarian as opposed to deontological ethics?
2. How do you think the three economic questions would be answered in a pure market system of allocation? Be precise. How do you think the three economic questions would be answered in a commune? What are some of the advantages and disadvantages of these two economic systems?

Internet Links

Aristotle's *Nicomachean Ethics*: (http://www.vt.edu/vt98/academics/books/aristotle/ni_ethic).

Hobbes's *Leviathan*: (http://www.vt.edu/vt98/academics/books/hobbes/leviathan).

Kant's *Metaphysics of Morals*: (http://www.vt.edu/vt98/academics/books/kant/pr_moral).

Locke's *Second Treatise on Civil Government*: (http://www.vt.edu/vt98/academics/books/locke/c_govern).

Northwest Forest Plan: (http://www.fs.fed.us/r6/nwfp.htm).

Rousseau's *Confessions*: (http://www.vt.edu/vt98/academics/books/rousseau/confessions).

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3

The Economics of Market Allocation

Introduction

In this chapter we will learn the fundamentals of neoclassical market microeconomics, with particular attention to the conditions that are required for the existence of a well-functioning competitive market. We will also learn what it means to say that this market will efficiently allocate scarce resources in equilibrium. The conditions required for such a market to function may fail to hold, however, and so we will find out how markets are distorted and how efficiency is impaired by these market failures. This basic understanding of market economics will then form the analytical framework for the chapter that follows, which reviews the theory of externalities and forms the economic argument for environmental regulations.

Market Capitalism: Overview and Definition

Overview

We have probably never seen a pure version of market capitalism in recorded history, and it is unlikely that we ever will, for reasons discussed below. Perhaps the closest we have come to a pure system of market capitalism would be nineteenth-century Great Britain and the United States prior to the advent of extensive systems of health, safety, environmental, employment, and social regulation on markets and business enterprises. An argument can also be made that Hong Kong under British rule was the least-restricted capitalist society in the world. Markets have existed to some degree or another for thousands of years, as evidenced by ancient trade routes in almost all land areas occupied by humans over the last 2,000 to 4,000 years (or more). In the European experience, market capitalism developed in the 1200s in the northern Italian city-states and Flanders in Europe, and reached its “golden age” in Great Britain during the Industrial Revolution. Market capitalism was quite radical in its early years, for it provided a new class of merchants and others who, through their own enterprise, could rise up from narrowly prescribed and rigid class boundaries formerly maintained by the powerful aristocracy–church monopoly on land and wealth.

Definition

Market capitalism is a socioeconomic system in which scarce resources (and the goods and services into which they are transformed) are allocated by way of a complete set of *decentralized markets*. As used here, the term *decentralized* means that systemwide resource allocation occurs as a consequence of many individual market transactions, each of which is guided by self-interest. Adam Smith’s famous “invisible hand” of the market refers to the remarkable outcome of efficient systemwide resource allocation that results from individual self-interest rather than the “visible hand” of socialist systems in which allocation decisions are made by centralized planners at some level of community or government control. In all systems other than slave states, individuals own their own labor. Under capitalism, individuals rather than governments or collectives also own the other factors of production, land, and capital. Thus, the three economic questions identified in chapter 2—(1) what to produce, (2) how to produce, and (3) for whom goods and services are produced—are answered under capitalism by (1) consumer demand for various goods and services markets, (2) the least cost production technology, and (3) those consumers with the willingness to pay.

The Efficiency of Competitive Markets

Will all markets tend to be efficient, or are there some conditions that must hold? A central tenet of neoclassical microeconomic theory is that a well-functioning competitive market in equilibrium is efficient. Before we explain why this is so, let’s first define a few terms.

A well-functioning competitive market has the following properties:

- There are well-defined and enforceable property rights that define the ownership of resources, goods, and services.
- There is a functioning market institution that is made up of the various rules governing how buyers and sellers interact, particularly how price and other terms of trade are set.

- Neither buyers nor sellers have market power due to collusion or monopolization.
- There are no positive or negative externalities (described below and in chapter 4).
- There is the potential for low-cost entry by new sellers or buyers, which further limits the potential for collusion or monopolization. Exit is also low-cost, which reduces the risk of entering the market.
- Transaction costs, such as legal fees, taxes, or regulatory requirements, are sufficiently low that they do not choke off mutually satisfactory transactions.
- Information on characteristics such as the quality, availability, pricing, and location of goods and services is available at low cost to market participants.

Market failure occurs when one or more of the above conditions for a well-functioning competitive market is not met in a substantial way. We will discuss this in much greater detail below.

Market equilibrium occurs at a price where the quantity supplied by sellers equals the quantity demanded by buyers. Because quantity supplied equals quantity demanded there is neither a shortage nor a surplus. This state of affairs is referred to as an "equilibrium" because the price and the volume of trade will stay the same over time until some factor influencing buyer or seller market behavior changes, which will then necessitate a period of adjustment as price seeks its new equilibrium level. If markets are frequently buffeted by shifts in buyer or seller behavior, price may be nearly continuously shifting. *Efficiency* generally refers to the condition of minimal waste. We will wait a bit before we explain the concept of efficiency as it is applied to market systems.

Consider the hypothetical example of a single, individual market in Table 3.1.

Markets are made up of a number of buyers and sellers and an institution governing how buyers and sellers communicate and trade. In neoclassical microeconomics, buyers are assumed to have the objective of maximizing their overall level of satisfaction, or utility, but are constrained in this endeavor by their income and by market prices. Accordingly, each unit of each available good or service contributes a gain in utility, referred to as *marginal utility*. The maximum amount of money that a consumer is willing to pay for a unit of good or service (known more simply as "willingness-to-pay") is directly related to the marginal utility generated by consumption of the good or service, and to the consumer's income. In contrast, the availability of substitutes at relatively low prices tends to reduce a buyer's willingness to pay. Different buyers have different preferences and incomes, and so have different willingness-to-pay values for the same good or service. By adding up the

Table 3.1

Hypothetical Supply and Demand Schedule Data

Price	Quantity supplied	Quantity demanded
1	10	90
2	20	80
3	30	70
4	40	60
5	50	50
6	60	40
7	70	30
8	80	20
9	90	10
10	100	0

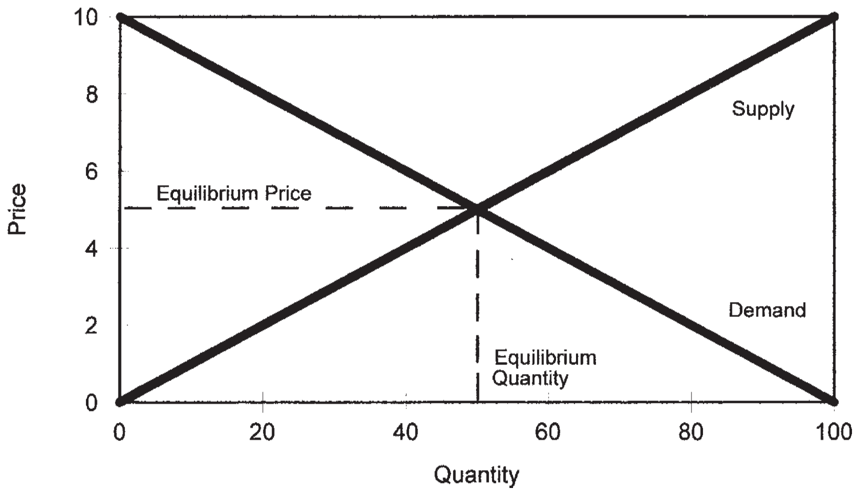
quantity demanded by each buyer at a given market price, one can arrive at quantity demanded in an entire market, as shown in Table 3.1.

According to the *Law of Demand*, there is an inverse relationship between price and quantity demanded. If we hold constant the factors other than price that influence buyer purchase decisions (such as income and the price of substitutes), then the inverse relationship between price and quantity demanded can be graphed as a *demand curve*. If market price is high, only those few buyers with high willingness-to-pay values will make a purchase, and so quantity demanded is low. These will tend to be higher-income buyers and/or those who receive a high marginal utility from the good or the service. If market price were to be considerably lower, then those few with high willingness-to-pay values will purchase and receive a bargain, and other buyers with lower willingness-to-pay values will also purchase, and so quantity demanded increases. This is why a store can clear excess unsold inventory by placing overstocked goods on sale at a reduced price.

Sellers are assumed to be maximizers of profit in neoclassical microeconomics. Sellers exhibit a willingness to supply a certain quantity of a good or service that varies directly with price. In other words, a higher price provides sellers with an incentive to increase quantity supplied in the market, while a lower price creates an incentive to reduce quantity supplied. This relationship is sometimes referred to as the *Law of Supply*. This issue is discussed in greater detail in chapter 4. By adding up the quantity supplied by each seller at a given market price, one can arrive at the market quantity supplied in Table 3.1. If we hold constant the factors other than price that influence sales decisions (such as labor and other input costs, technological innovation, and regulations), then the direct relationship between price and quantity supplied can be graphed as a *supply curve*.

The data from supply and demand schedules can be plotted as supply and

Figure 3.1 **A Typical Competitive Market**



demand curves, as illustrated in Figure 3.1. Note that at a price above $5, there is a *surplus* of goods or "excess supply" (quantity demanded less than quantity supplied), and at a price below $5, there is a *shortage* of goods or "excess demand" (quantity demanded greater than quantity supplied). When there is a surplus, market forces lead to a reduction in price. For example, if a retailer overestimated demand for a new line of clothing, then unsold inventory would result unless price were reduced, perhaps through a clearance sale. Likewise when there is a shortage, market forces lead to an increase in price. For example, if a retailer or manufacturer underestimated demand for a new toy, then demand would far outstrip supply unless price was increased. The equilibrium price occurs when quantity supplied equals quantity demanded.

Mutually satisfactory market transactions are Pareto efficient when compared to status quo of no trade. The reason is that buyers and sellers engaging in mutually satisfactory market transactions each receive a *gain from trade*, which enhances their *welfare* relative to the status quo. Buyers have a maximum price they are willing to pay for a given quantity of the good (their demand) and receive a gain from trade called *consumer surplus* when their willingness-to-pay value is larger than the price they had to pay. When people "get a bargain" at an auction or a garage sale, they are experiencing consumer surplus. Because the market demand curve represents the willingness-to-pay values of all the buyers in the market, total consumer surplus is the area in Figure 3.1 between the demand curve and market price. Sellers receive a symmetrical gain from trade, called *producer surplus*, when market price exceeds those costs that must be covered to make a sale worthwhile. Producer surplus is the area in Figure 3.1 between the supply curve and market price. The sum of consumer and producer surplus is total surplus, the total gain from voluntary exchange in this market. We measure the overall *welfare* of the market participants based on total surplus. Note that an Excel-based simulation is available on the Internet site for this textbook, which will help you learn how to use linear supply and demand equations to solve for a competitive equilibrium and compute the gains from trade (ftp://sorrel.humboldt.edu/pub/envecon/module1.xls).

Efficiency

The generic definition of *efficiency* is the condition of producing something beneficial or valuable with a minimization of waste. There are many different ways that the word "efficient" is used, such as fuel-efficient, time-efficient, and Pareto-efficient, and this multitude of different ways of specifying efficiency can be confusing. Now we are going to add a new type of efficiency. In the context of market analysis, *resources are efficiency allocated* when the welfare of the market participants (as measured by consumer and producer surplus) is maximized. In other words, resources are efficiently allocated when the maximum possible gains from trade are realized by the market participants. Resources are efficiently allocated at the equilibrium market price because there are neither shortages nor surpluses, and so there is neither too much nor too little produced. If price were above the equilibrium level, we would have a surplus, and so the amount traded (equal to quantity demanded) would be less than the quantity traded at the equilibrium price. If price were below the equilibrium level, we would have a shortage, and so the amount traded (equal to quantity supplied) would be less than the quantity traded at the equilibrium price. As a result, when there are either shortages or surpluses, some mutually satisfactory transactions are prevented from occurring that would have generated consumer and producer surplus, which is why nonequilibrium prices are inefficient.

Although there is a tendency to ignore the functioning of markets, or to take them for granted, Hayek (1937, 1945) focused attention on the fact that the price system in competitive markets provides a unique means of conveying and exploiting information. While Adam Smith argued that the self-interested interaction of many buyers and sellers results in efficient production and allocation, Hayek went further by observing that markets are the only way of bringing together the widely dispersed information necessary for efficient production and allocation. Hayek said that the reason why centrally planned socialist systems have such great difficulties is that they require the central planners to somehow embody all the information held by producers and consumers in markets. In setting prices and quantities, and in choosing technologies and levels of employment, the central planner must somehow know the willingness-to-pay of all consumers, the production costs of all sellers, and the most efficient means of organizing production. Planners must also know how to adjust prices and quantities in response to external factors such as fluctuations in the price of substitutes, consumer income, input price changes, regulatory impacts, new technologies, changes in the workforce, and weather. The appropriate adjustment to prices, quantities, and methods of production relies upon the knowledge held by large numbers of independent consumers and producers, and according to Hayek it is not possible for central planners to gather, process, and act upon this dispersed knowledge. According to this view, prices, quantities, and methods of production will only reflect dispersed information when they are determined in competitive markets.

Unfortunately, the conditions required for efficient markets are not always met. For example, if consumers are misled by exaggerated quality claims, demand for the good is exaggerated, leading to excessive consumption and negative gains from trade for those who later realize that their willingness-to-pay based on actual quality is less than the price they paid. If sellers can shift costs to society as a whole by polluting rather than paying for cleanup, then (as we will learn in chapter 4) the market supply curve will be shifted out to the right and excessive consumption occurs. In either case the market's failure to integrate knowledge is not so different from the failings of Hayek's central planners. When markets fail to be efficient, there is an economic argument for some form of government intervention, such as regulation.

Market Failure

Most markets are less than perfectly efficient. When these inefficiencies are substantial, we refer to such a state as a *market failure.* Let's consider some of the possible sources of market failure.

Monopoly, Cartels, and Market Power

A monopoly exists when there is a single seller in a market. A cartel is a group of colluding sellers that collectively act like a monopolist. Competition fails under these conditions. In order to raise price and profit, a monopolist or a cartel will need to reduce output from the competitive level. This can be more difficult for cartels because the reduction in output must be coordinated among all cartel members. If a monopolist or a cartel is successful in reducing output relative to the competitive equilibrium level, price will rise along the demand curve. Because the price rises, monopolists and cartel members are able to transform some consumer surplus into producer surplus. As output must be reduced in order for price to rise above competitive levels, the decline in output implies that some mutually satisfactory transactions that produce consumer and producer surplus do not occur. By how much will monopolists and cartels reduce output relative to competitive levels? A point will eventually be reached beyond which the producer surplus lost from further reducing output will outweigh the producer surplus gained from the resulting increase in price. Because monopolies and cartels produce less than the competitive equilibrium level of output, resources are not efficiently allocated in the market (too small a quantity is produced), and the sum of producer and consumer surplus is less than in the competitive equilibrium. In addition, from an equity or fairness perspective, monopolized or cartelized markets give undue power to the sellers. Government intervention in the United States occurs by way of state and federal *antitrust laws*, which provide criminal and civil sanctions for monopolized or cartelized markets.

Externalities

As we shall discuss in much greater detail in chapter 4, *externalities* are unpaid-for benefits or uncompensated costs that impact society as a by-product of production and exchange. The term *externality* refers to the fact that these benefits or costs are not reflected in market demand and supply. *Positive externalities* are external benefits generated from production and exchange and enjoyed without payment by members of society. An example would be the benefits to neighboors when homeowners beautify the neighboorhood by landscaping their yards, or when work is done to improve adjoining roads and sidewalks. Because those who benefit from positive externalities do not pay for them, their willingness-to-pay is not included in market demand, and accordingly, market demand is too small. In the example given above, the market for landscaping materials and services will produce an inefficiently small quantity because the external benefits enjoyed by the neighbors are not reflected in market demand.

Other examples of positive externalities include the external benefits from vaccinations for infectious disease (reduced likelihood of epidemic), the external benefits from literacy and education in a democratic society (more informed voting and civic participation), and the external benefits from land stewardship practiced by farmers, ranchers, and timberland owners (reduced likelihood of flooding, improved groundwater quality, open space, and so forth). In each case the buyers in the market receive private benefits, but there are also external benefits that are not included in the market, which is why an inefficiently small quantity is produced by the market.

Negative externalities are external costs generated from production and exchange and borne without compensation by members of society. The prime example is pollution generated as a by-product of producing electricity. Profit-maximizing firms in otherwise well-functioning competitive markets have an incentive to pollute if doing so allows them to reduce their own costs and thus raise their profits. As will be explored in much greater detail in chapter 4, because firms that emit external costs do not have to pay these costs, the market supply curve is too large, and too large a quantity is produced in the market. In the example given above, the market for electricity will produce an inefficiently large quantity of electricity because the external costs borne by people and the environment are not reflected in market supply. Consequently, even well functioning competitive markets can be inefficient when there are substantial pollution externalities.

Government intervention for positive externalities takes the form of a subsidy to consumers (or producers). For example, a city or county government might provide subsidized vaccinations for infectious disease, provide free or subsidized education, and use tax dollars to purchase conservation easements to subsidize appropriate land stewardship from farmers, ranchers, and timberland owners. In the case of negative externalities, government regulations take the form of state and federal environmental rules that impose criminal and civil penalties, taxes, or outright bans on polluters.

Common-Pool Resources and Public Goods: Collectively Produced and/or Consumed Goods

Some goods and services have the characteristic that individual property rights are not assigned, and so they are collectively produced and/or consumed. Examples include parks, highways, emergency services, marine fisheries, rivers, groundwater basins, air, public radio, wilderness areas, and recreation sites. The two categories of collectively consumed goods that are relevant to this book are *common-pool resources* and *public goods*. A common-pool resource (CPR) is distinguished by the characteristics that (1) it is difficult to exclude multiple individuals who appropriate from the resource stock, and (2) the resource features rivalry in consumption or subtractability, meaning that resource units appropriated by one subtract from what is available to others. In contrast, while it is difficult to exclude multiple individuals who benefit from public goods, these goods differ from CPRs in that they lack rivalry in consumption. For example, a coastal fishery is a CPR because fish harvested by one subtract from what is available to others at a given point in time, but public television broadcasts are public goods because one person's reception of the broadcast does not subtract from what is available to other viewers.

These goods tend to be underproduced and/or overconsumed when they are allocated in markets. For human-made goods that are collectively consumed, such as public radio and television, self-interested individuals have an incentive to *free ride* on the provision efforts of others. Because few are willing to pay for something that they believe will be provided by others, market demand for these goods and services is far too low, leading to an inefficiently small quantity provided in markets. How many of us listen to public radio or watch public television but rely on others to support it? Because the inputs that people provide—such as personal effort or financial contributions—are privately owned while the output is collectively consumed, provision of the good is a positive externality and thus is underprovided in market systems. If the benefits flowing to free riders were included in the market, such as through compulsory taxes or user fees, market demand would shift out and a larger equilibrium quantity would result. Hence, free riding leads to an inefficiently low quantity provided through the market. Appropriate government intervention may be public provision by way of taxes or compulsory user fees, such as the use of taxes to fund the Corporation for Public Broadcasting.

While the problem of underprovision affects both CPRs and public goods, the problem of overconsumption is specific to CPRs. Those who appropriate from CPRs such as ocean fisheries, oil fields, groundwater basins, and congested roads and public parks have an incentive to overuse the good, which can lead to deterioration unless rule systems are put into place to limit use. This process is sometimes known as the *tragedy of the commons*. At the heart of the tragedy of the commons is an *appropriation externality*, where an individual's appropriation activity yields benefits to the individual, but imposes the cost of reduced resource availability on all appropriators. Because these incentives operate on all who use the CPR, the appropriation externality leads to a race to appropriate resource units. In this case, appropriate government intervention may take the form of rules and regulations limiting use and harvest from CPRs; CPRs (and to a lesser extent public goods) will be discussed in greater detail in chapters 5 and 15.

Imperfect Information

If people are poorly informed of product quality, safety, or availability, then their willingness-to-pay is distorted, which in turn implies that market demand is either too large to too small. Consequently, either too much or too little is produced relative to the full-information benchmark, leading to an inefficiency. For example, if buyers are poorly informed about a product's quality prior to purchase, there is an incentive for a "fly-by-night" seller to overstate quality. In this case, demand is overstated because buyers think quality is higher than it actually is, and so the equilibrium quantity traded is inefficiently large. If employers understate workplace hazards, then the supply of labor to these employers will be overstated, leading to a wage below what workers would demand if true workplace safety were known. If market participants do not resolve the imperfect information problem through such things as product warranties and reputation, then either government or non-government organizations may intervene by providing information. Examples include content labels required on processed food, or product testing services provided by the Consumer Union.

Fairness, Equity, and Distributive Justice

The efficiency properties of well-functioning competitive markets have nothing to say about the underlying fairness with which resources, wealth, and income are distributed in society. Such a market is efficient because it maximizes the available gains from trade, yet others in society may place a high value on the good or service being produced but lack the income to be able to represent this value as willingness to pay. Yet it can also be argued that it is fair that those who work harder, produce more, or find innovative ways to cut costs or save energy should be compensated for their added contributions. If this is not the case, then there is no financial incentive to work harder or to innovate. Because capabilities and access to education and skills are unevenly endowed in the population, rewarding productivity leads to inequality in society. Moreover, those who succeed can give more to their children, affording them a better start and helping them to succeed, which can worsen inequalities over time and lead to a cycle of poverty. Economies of scale and differences in the successes of firms also lead to concentrations of a few firms in many markets, leading to a weakening of the competitive process. Balancing incentives and equality is one of the central dilemmas with which all societies are confronted.

Perspectives on Market Failures and Government Intervention

As we can see, there are almost no examples of real-world markets that do not have some degree or another of market failure, often of various dimensions and degrees. From an economic perspective, then, there is potential for regulatory intervention of some kind to resolve market failures in most markets. Such intervention, however, can itself create problems and distortions. Thus, when we see an opportunity for a regulatory intervention because of market failure, it is also worthwhile to consider whether the form of intervention being contemplated truly makes us better off. The particular form that regulations take may at times be more a reflection of political expediency than economic efficiency, a condition sometimes referred to as "government failure." We will discuss this point in the chapter on political economy and in the chapter on incentive regulation.

Summary

- We have defined *capitalism* as an economic system based on the use of a complete set of "decentralized markets" (as opposed to socialist systems, in which allocation decisions are centralized at some level of community or government control) to allocate scarce resources, goods, and services. Capital is privately owned by individuals, and production and employment decisions are decentralized.
- It has been pointed out that there have been no true tests of pure *laissez-faire* (fully unregulated market capitalism) in recent history. It is unlikely to be in the best interests of society as a whole to practice pure laissez-faire capitalism because of market failures and because of inequalities heightened by capitalism.
- A well-functioning competitive market is the primary benchmark for evaluating market failures and the need for public policy intervention. For a market to be well-functioning and competitive, there must be many individual buyers and sellers, each of whom is small relative to the overall market; market entry and exit costs must be inconsequential; current and potential market participants must be fully informed of prices, qualities, and location; transaction costs must be low; there must be no collusion among the market participants; and there can be no consequential positive or negative externalities.
- When any of the above conditions are substantially absent, a *market failure* has occurred, meaning that the market no longer meets the conditions for being well-functioning and competitive.
- Economists argue that market failures are a central justification for public policy intervention in market capitalist systems if these interventions are designed to compensate for the market imperfections and the interventions do not create a larger distortion than the market failure itself.
- We discussed the theoretical requirements for efficient markets to be in *equilibrium*, namely, that the quantity supplied by sellers equals the quantity demanded by buyers at the prevailing price, and so there is neither a shortage nor a surplus. The market allocation is *efficient* because neither too much nor too little is produced, and thus there is no

waste. Another aspect of efficiency is that all of the available gains from trade in the market are realized by the market participants, with none wasted, meaning that the sum of producer and consumer surplus is maximized.

- In the next chapter we shall discuss market failures based on externalities and the role of this form of market failure in justifying environmental regulation.

Review Questions and Problems

1. Consider the demand and supply for used science textbooks. Suppose that the used-textbook market is competitive, with supply given by $P = 10 + .1Q$ and demand given by $P = 100 - .08Q$. Solve for the competitive market equilibrium price and quantity of used textbooks in this market. Determine the quantity of shortage or surplus that would occur if a price ceiling (maximum allowable price) of $35 were imposed on this market. Describe why the market fails to be efficient in the context of this ceiling and what market participants commonly do to overcome the inefficiency caused by official prices below the equilibrium market price. If the intention is to help low-income students, compare the effects of the price ceiling to an alternative scheme of giving $25 purchase vouchers to low-income students. In your answer, consider the effect of the vouchers on the demand for textbooks.

2. Starting with a supply-and-demand diagram as in Figure 3.1, identify producer and consumer surplus in the competitive equilibrium. Now suppose that sellers form a cartel and reduce their total output in order to increase producer surplus. Illustrate in your diagram how a reduction in output will (i) transform some consumer surplus into producer surplus, and (ii) result in a reduction in total surplus due to the loss of some mutually beneficial transactions.

3. Go back to the example in Table 3.1. Suppose that the data represent the hourly market for burrito lunches in a community with five Mexican restaurants, and that at the equilibrium price of $5, the restaurants are highly profitable. Now assume that the profitable nature of this business attracts entry by a sixth Mexican restaurant. Make up a new hypothetical supply schedule and show how this entry affects price and quantity in the market.

Internet Links

Antitrust Division of the U.S. Department of Justice (http://www.usdoj.gov/atr/index.html): The mission of the Antitrust Division is to promote and protect the competitive process through enforcement of the antitrust laws. The antitrust laws apply to virtually all industries and to every level of business, and they prohibit a variety of practices that restrain trade, such as price-fixing conspiracies, corporate mergers likely to reduce the competitive vigor of particular markets, and predatory acts designed to achieve or maintain monopoly power.

Consumer Products Safety Commission (http://www.cpsc.gov/): An independent agency of the U.S. government, the CPSC helps keep American families safe by reducing the risk of injury or death from faulty or hazardous consumer products.

Dead Economists Society (http://cac.psu.edu/~jdm114/): Dedicated to the appreciation of classical liberal economics and laissez-faire capitalism, including free markets, limited government, and private property.

Federal Trade Commission (http://www.ftc.gov/): The Federal Trade Commission (FTC) enforces a variety of federal antitrust and consumer protection laws, and it seeks to ensure that the nation's markets function competitively, and are vigorous, efficient, and free of undue restrictions. The FTC also works to enhance the smooth operation of the marketplace by eliminating acts or practices that are unfair, deceptive, or threaten consumers' opportunities to exercise informed choice.

History of Economic Thought Website (http://cepa.newschool.edu/het/): Produced by the New School for Social Research, here you can read about the entire spectrum of economic thought.

Interactive Supply/Demand Simulation (ftp://sorrel.humboldt.edu/pub/envecon/module1.xls): An Excel-based interactive simulation available on the Internet site for this textbook that will help you learn how to use linear supply and demand equations to solve for a competitive equilibrium and compute the gains from trade. Click "yes" to enable macros. You do not need to know how to use Excel to access this simulation as it is entirely menu-driven.

International Association for the Study of Common Property (http://www.indiana.edu/~iascp/): Lots of useful material related to common-pool resources and the ownership regime of common property.

Marx/Engels Library (http://csf.colorado.edu/mirrors/marxists.org/archive/marx/works/): A site where you can read the works of the great critics of laissez-faire capitalism.

References and Further Reading

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4

Externalities, Market Failures, and Policy Interventions

Introduction

In this chapter we continue the discussion of markets and efficiency by evaluating the economic theory of externalities. We will evaluate externalities in the context of an otherwise well-functioning competitive market system. *Externalities* are positive or negative impacts on society that occur as a by-product of production and exchange. These effects are called externalities because they are not included in the factors that underlie market supply and demand, and their omission leads to the market failing to allocate resources efficiently. The inefficiency due to externalities can be used as a justification for government intervention in otherwise well-functioning competitive market systems. Externality problems are not unique to market systems, however, as illustrated by the profound environmental pollution that occurred in the former Soviet Union and its Eastern European satellite states.

In the section that follows we will begin with a discussion of positive externalities, the distortion they create in the market, and possible policy interventions that have the potential for enhancing market efficiency. Next, we will turn to negative externalities. Because pollution is such a persistent and encompassing problem, we will evaluate the source and the consequences of negative externalities in greater detail.

Positive Externalities

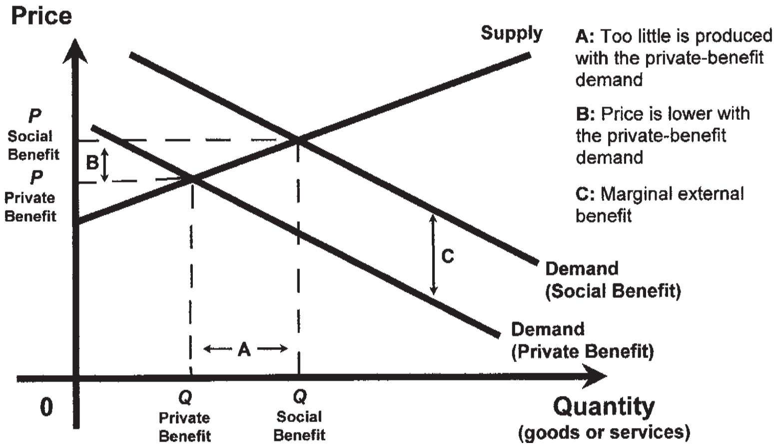
Consider pastureland near a growing urban area that can be used either for livestock grazing or converted into new housing, schools, roads, and retail development. Pastureland produces benefits for local residents such as open space, vistas, wildlife habitat, and temporary floodwater storage. If local residents receive these benefits without having to pay for them, then these benefits are external to the market process. Pastureland is bought and sold in markets, however, and the market demand for pastureland is based on the *private benefits* that flow to the buyers, such as revenues from grazing cattle, stabling horses, producing hay, or selling to a developer. Consequently, the market demand for pastureland ignores the external benefits received by others who do not pay for them. Because market demand does not reflect the external benefits of intact pastureland that flow to society, the market process will allocate *less than the socially optimal amount* of such land as pasture, leading to excessive agricultural land conversion and urban sprawl.

A *positive externality* can be defined as an unpaid-for benefit enjoyed by others in society that is generated as a by-product of production and exchange. Positive externalities are also known as "external benefits." For example, as a by-product of purchasing a college education, a college student produces external benefits to society in the form of being an informed voter and a resourceful citizen. Likewise, as a by-product of a parent vaccinating her child for infectious disease, an immunized child reduces the likelihood of a disease epidemic spreading to others in society. The pastureland example above offers yet another example of a positive externality. While positive externalities are nice for those who get them, otherwise well-functioning competitive markets are not efficient at providing them. Specifically, when goods are purchased by buyers in a market, the market demand for the good reflects the private benefits that flow to the buyers. Because those who receive positive externalities do not pay for them, market demand does not include external benefits.

The sum of private benefit and external benefit is called *social benefit*. Figure 4.1 indicates how the demand based only on private benefits is smaller than (to the left of) the demand curve based on social benefits. The vertical difference between the private-benefit and the social-benefit demand curves is *marginal external benefit*, or the external benefit per unit of output, as indicated by the letter *C* in Figure 4.1. In the pastureland example, marginal external benefit would be the external benefits from an additional acre of intact pastureland (open space, vistas, wildlife habitat, and temporary floodwater storage). The marginal concept will be developed more completely for the case of negative externalities later in the chapter.

As shown in Figure 4.1, the market demand curve based on social benefits exceeds (lies to the right of) the market demand curve based only on private benefits. Because buyers' willingness-to-pay only reflects their private benefits, only the market demand based on private benefits will exist in the market. As the demand based on private benefits is smaller than the demand

Figure 4.1 **Positive Externalities and Market Failure**



based on social benefits, an otherwise well-functioning competitive market will underprovide those goods (pastureland, education, vaccinations) that generate positive externalities. This underprovision is indicated by the letter *A* in Figure 4.1. If society intervened in the market by using tax revenues to subsidize buyers, then market demand would reflect both social benefits and the efficient quantity of those goods (pastureland, education, vaccinations) that generate positive externalities. For example, in the case of pastureland, many counties have open space districts that tax residents and use those tax revenues to purchase *conservation easements*. When a farmer sells a conservation easement on her land, she and any future owner no longer has a right to convert the pastureland to housing, roads, or other developments that might impair the open space and ecological services provided by the land. By purchasing the easement, society internalizes the positive externality.

It should be noted that not all positive externalities are limited to distorting the market demand curve. One well-known example is a *technology spillover*, which distorts the market supply curve. For example, the Apollo space program led to the development of many new products and technological innovations that spilled over into commercial market applications. Similarly, military and National Science Foundation–sponsored efforts helped to create the basic Internet structure that has transformed the way that people communicate and conduct business. Technology spillovers are unpaid-for benefits, and many of them reduce production costs, enhance productivity, and thus shift out the supply curve. Commercial buyers in the market for research and technology only take into account the private benefits that they hope to receive, and not beneficial technology spillovers, and thus there is an inefficiently small amount of basic research conducted by private enterprise.

This is one reason why government subsidizes basic research, which has the potential for technology spillovers.

Negative Externalities

Consider cabinet manufacturers that can use two alternative production processes for making finished cabinets. Process A costs the firm less than nontoxic process B, but process A allows toxic volatile organic compounds from the wood-finishing process to escape into the atmosphere. These volatile organic compounds contribute to smog and thus impose *external costs* on people who breathe the polluted air but who are not compensated for these harms. Because process A has lower *private costs,* profit-maximizing firms will usually choose it over the nontoxic alternative, which allows them to supply furniture at lower prices to consumers. As the supply of cabinets in the competitive furniture market does not reflect the external costs borne by members of society, the market process will allocate *more than the socially optimal amount* of cabinets when they are produced with the more polluting technology.

A *negative externality* can be defined as an uncompensated harm to others in society that is generated as a by-product of production and exchange. Many negative externalities occur as a by-product of market transactions. Pollution is the prime example of a negative externality, as illustrated in the cabinet example above. The harms created by pollution are known as "external costs." As we will see below, when market exchange generates negative externalities, market supply fails to reflect the true social cost of producing the good generating the externality, and so too much of the good is produced.

Following Scitovsky (1954) one can draw a distinction between *technological* and *pecuniary* externalities, and when economists refer to externalities, they usually mean technological externalities. A pecuniary externality occurs, for example, when a new firm enters a market. This entry will initially increase market supply and will tend to reduce market price, reducing the profit of other sellers. This is a negative pecuniary externality because it affects the profits or financial circumstances of another individual or firm, and the harm is directly transmitted by way of the market process. From an economic perspective, however, pecuniary externalities do not generate a misallocation of society's scarce resources, and thus are not considered a market failure. In contrast, a technological externality is a "peculiarity of the production function" (Scitovsky 1954, p. 145) in which the production process generates external costs such as pollution whose harms are not directly transmitted by way of the market process. As we shall demonstrate below, technological externalities such as pollution do in fact result in a misallocation of society's scarce resources and so are a form of market failure. When we refer to externalities in this textbook, we will mean the technological form rather than pecuniary form.

Property Rights and Negative Externalities

If negative externalities are uncompensated harms generated as a by-product of production and exchange, why don't those who bear these costs simply use the legal process to sue polluters for damages? The common-law tradition in the United States and elsewhere protects the integrity of property rights. Property rights represent an enforceable authority to undertake particular actions in specific circumstances (see Commons 1968). Thus, if someone is known to have dumped garbage on your front yard, this act is punishable (through criminal and/or civil penalties) because it impairs the value of your property. Certain aspects of our environment, including the air, ocean, wildlife, and groundwater, were not traditionally owned by anyone, and so damage to them did not directly impair the value of someone's property. Consequently, the common law did not provide criminal and/or civil penalties for damage to valuable but unowned aspects of the natural world. Both government and common property rights regimes have developed to prevent degradation of valuable resources that are not privately owned (see Bromley 1989, and Ostrom 1990).

Schlager and Ostrom (1992) identify five important property rights that, when bundled together, make up ownership:

- *Access:* The right to enjoy benefits of the property that do not subtract from benefits that others can enjoy, such as walking along the beach. Authorized entrants have access rights, such as those which are purchased with entry fees at national parks.
- *Withdrawal:* The right to withdraw the product of the property, such as harvesting fish from a fishery. Authorized users have both access and withdrawal rights, such as those that are acquired with the purchase of a fishing license or a firewood gathering permit from a national forest.
- *Management:* The right to regulate use and improvements. Ostrom (1997) uses the term *claimant* to refer to those who hold access, withdrawal, and management rights, such as farmers who participate in the management of government-owned irrigation systems.
- *Exclusion:* The right to determine who has access and who can be excluded from using the property. Ostrom (1997) uses the term *proprietor* to refer to those who hold access, withdrawal, management, and exclusion rights. Citizens of Swiss villages who possess and govern their own common property pastures and forests are proprietors in this sense.

- *Alienation*: The right to sell or lease. "Owners" possess all the rights of proprietors along with the right of alienation. Private property falls under this category, though owners can also be governments or communities.

We can see that there is more to property rights than ownership. Under some circumstances people have relatively limited rights, such as those of an authorized entrant or an authorized user. For example, someone with a valid fishing or hunting license is an authorized user with certain rights to harvest fish and game, while government owns the wildlife in a public trust capacity. *Usufructuary rights* refer to certain use and withdrawal rights granted to property that is owned by others. For example, treaties ceding Indian lands to the federal government sometimes include clauses granting Indian tribes usufructuary rights for hunting, fishing, and gathering on the ceded lands. Likewise, the right to appropriate from navigable waters in the United States is a usufructuary right, with the waterway itself being owned by government in a public trust capacity. California water law is built on the notion that the right of property in water is usufructuary. California Water Code section 102 provides that "[a]ll water within the State is the property of the people of the State, but the right to the use of water [usufructuary rights] may be acquired by appropriation in the manner provided by law."

Property rights scholars distinguish four different classes or regimes based on who holds property rights:

- *Private property rights:* Rights held by individuals and business enterprises, usually with a legally recognized owner.
- *Common property rights*: Rights held by an identified group of proprietors.
- *State property rights:* Rights held by government.
- *Open access:* No specific property rights recognized, and thus the resource is open to all under the common law rule of capture, with no capacity for management or exclusion.

As we saw in chapter 2, property rights to land and other resources originate from open-access conditions. Property rights can originate from being the first to make a valid claim for an unallocated open-access resource (such as the Homestead Act for land and the prior appropriation doctrine for water in the frontier West). Property rights can also originate by conquest (taking of other people's property), the assertion of government regulatory rights, or capture (removing resource units from an open-access or a common-property resource such as water, marine fisheries, or oil and gas). As Hanna (1996) states:

> Property rights regimes do not exist as two opposing types but rather as combinations along a spectrum from open access to private ownership. . . . Second, no single type of property rights regime can be prescribed as a remedy for [all] problems of resource degradation and overuse. . . . The key attribute of an effective property rights regime is that it is context-specific, reflecting environmental, economic, social, and political conditions. (p. 385)

Prior to the advent of environmental regulations, some types of pollution harms to private, common, or state property were punishable (at least in theory) under traditional common law as trespasses or as nuisances. Meiners and Yandle (1998), for example, describe some cases in which common-law penalties were extended to pollution affecting proprietors holding riparian water rights. In his more comprehensive historical treatment of the topic, however, McEvoy (1986) observes that this sort of enlightened application of common-law remedies to resource and environmental harms was not the norm in nineteenth-century America.

For our purposes it is important to observe that pollution or other harms to open-access resources such as breathable air were not usually punishable under common law. Therefore, if a profit-maximizing firm could avoid cleanup costs by polluting an open-access resource, there was generally no common-law legal penalty to deter such an action. The same was true if those who held private, common, or state property rights were unable to enforce their rights. This problem with the common law and open-access resources led to the development of environmental regulations. By vesting government with the authority to manage and by excluding certain uses of a resource, environmental regulation establishes a system of property rights to formerly open-access resources. We can see, then, that an important step in protecting the environment is assigning appropriate property rights. The type of property rights regime that is appropriate depends on factors such as the nature of the resource, the culture and values of society, and the costs of monitoring and excluding use. For example, resources such as air, oceans, groundwater, and fisheries are *fugitive resources*, meaning that it is difficult or impossible to brand individual resource units or partition the stock of the resource into individually owned parcels. Fugitive resources are less likely to be private property and more likely to be common property, state property, or open access.

In the sections that follow we will explore how negative externalities lead to market failure. To understand how externalities are linked to market failure, however, we must first understand how private costs and external costs are reflected in competitive markets by way of the supply curve.

Private Costs and the Supply Curve in Competitive Markets

A *supply curve* is defined as a graphical representation of the relationship between quantity supplied by firm(s) and price. As we saw in chapter 3, Table 3.1 provides supply schedule data linking price to quantity supplied. When these data are plotted on a graph the result is a supply curve. The Law of Supply states that price and quantity supplied are directly related, meaning that when price rises, quantity supplied will also rise, implying an upward-sloping supply curve. We will show that this direct relationship is caused by the shape of a competitive firm's short-run marginal costs. While the concepts are illustrated by example, a calculus-based description of supply curves is offered in the appendix at the end of this chapter. If you are already familiar with the economics of supply curves, you should skip ahead.

To understand the basis of supply curves, we will begin with a highly simplified production example. We assume that a cabinet-manufacturing firm has a shop of fixed capacity that it is committed to using during the relevant period of our analysis, and that the firm sells into a large competitive market. These competitive conditions effectively determine the going market price for the type of cabinets it makes, and the firm assumes it effectively cannot influence this market price. The daily cost data for this cabinet shop are given in Table 4.1.

One of the cost concepts illustrated in Table 4.1 is that of *marginal cost*. Marginal cost tells us how total costs change when the firm produces an additional increment of output. Therefore, marginal cost (or incremental cost) is defined as the change in total cost divided by the change in output. In this example, the firm can adjust its output of cabinets by varying the number of hours of labor it employs each day. Each time the shop increases hours worked, two things happen: output increases and costs increase. Thus, each time the number of hours worked increases, we can compute marginal cost. It is commonly assumed that marginal costs may decline at first as output increases, reflecting the fact that the first few additional hires allow all workers to *specialize* (e.g., cutting the wood, building the cabinet, finishing and staining the cabinet). Eventually, however, marginal cost will begin to rise, reflecting *congestion* (adding more and more carpenters to a given-sized shop means not enough tools and shop space to go around). The impact of labor congestion on productivity in the short run is a reflection of the *Law of Diminishing Marginal Returns*. One of the essential elements of microeconomic theory is the notion that diminishing marginal returns eventually occur in the short run. Diminishing marginal returns imply that marginal costs will increase with each incremental increase in output. In other words, the marginal cost curve for a competitive firm will eventually become upward sloping.

Table 4.1

Hypothetical Example of the Costs of Producing Cabinets

Fixed cost (shop & equip.)	Variable materials cost	Hours of labor employed	Output of cabinets	Total cost	Marginal cost
100	0	0	0	100	—
100	500	10	100	800	7
100	1,250	20	250	1,750	6.33
100	1,750	30	350	2,450	7
100	2,150	40	430	3,050	7.50
100	2,450	50	490	3,550	8.33
100	2,650	60	530	3,950	10
100	2,750	70	550	4,250	15
100	2,800	80	560	4,500	25

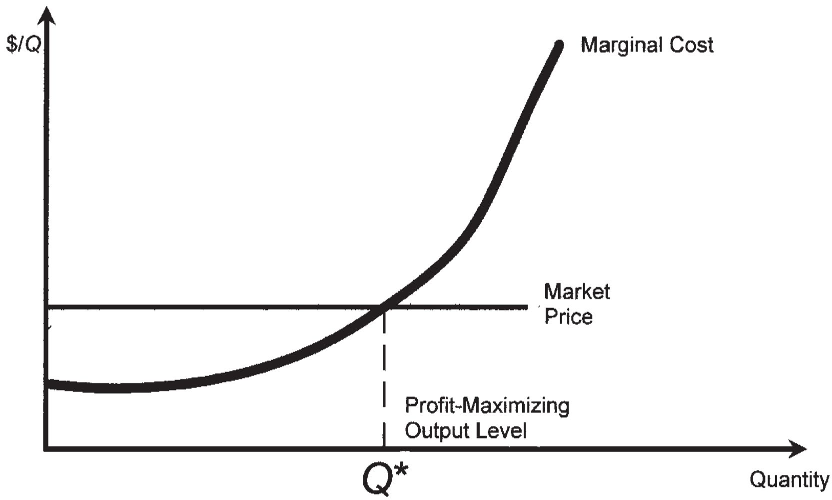
Note: The hypothetical data above are for daily production. It is assumed that the variable materials cost for each cabinet is a constant $5, that each carpenter is paid $20 per hour, and that the fixed cost from rental of the shop and equipment is $100 per day.

Now suppose that a profit-maximizing cabinet shop in a competitive furniture market is trying to find the most profitable level of output to produce. Microeconomic theory suggests that the firm should find this optimal output level by determining how its profits change as it incrementally increases output, starting from zero. Each time the cabinet shop incrementally increases its output of cabinets, its revenues and its costs both increase. If the increase in revenue (*marginal revenue*) is greater than the increase in cost (*marginal cost*), then the profits of the cabinet shop grow as output is increased. But at what level of output will profit be maximized, and these incremental increases in output end?

The answer to this question hinges on the upward-sloping marginal cost curve. Recall that as output increases, congestion and the Law of Diminishing Marginal Returns sets in (carpenters lacking adequate tools and work space), and marginal costs will begin to rise. Each cabinet produced and sold by the shop generates marginal revenue that is equal to the market sales price of the cabinet. Because the firm is small in size relative to the overall competitive market, its incremental increase in output has no effect on market price. Therefore, market price is independent of the firm's output, as shown in Figure 4.2.

You can see where this is going. As the firm increases its output in increments, its marginal cost rises while its marginal revenue remains constant at the market price of cabinets. At some point an increase in output will result in the marginal cost finally becoming equal to market price, meaning that production and sale of that last cabinet will contribute no further increase in

Figure 4.2 **Profit-Maximizing Output Found Where *P* = *MC***



profit (marginal revenue equals marginal cost). Moreover, if the firm were to produce an additional cabinet beyond this point, marginal cost would rise above market price, and that additional cabinet sale would actually reduce profit. As a consequence, a profit-maximizing firm in a competitive market will set its output where price equals marginal cost, as illustrated in Figure 4.2. This is an application of the *equimarginal principle* in economics. The equimarginal principle simply states that an optimal allocation occurs when the marginal benefit (in this case marginal revenue) equals marginal cost.

The next important step is to show that the firm's marginal cost curve is also its supply curve. To see this, notice that the firm will set quantity supplied where market price equals marginal cost. If market price rises, quantity supplied will also rise because the firm can now afford to produce at a higher point on its upward-sloping marginal cost curve. Likewise, if market price falls, quantity supplied will also fall because the firm cannot afford to produce at the previous point on its upward-sloping marginal cost curve. Because a firm's marginal cost curve tells us the relationship between price and the firm's quantity supplied, it is the firm's supply curve. The only exception is that when market price becomes sufficiently low, firms will avoid operating losses by shutting down and producing no output.

Table 4.2 illustrates the *P* = *MC* rule for three different wholesale cabinet prices ($7.50, $10, and $25). Note that the data in Table 4.2 are consistent with the description that preceded it, namely, that the firm's profits rise as it incrementally increases output until the point is reached at which price equals marginal cost. Thus, profits are at their maximum possible level when the

Table 4.2

Example: Profit Maximization Occurs Where Price Equals Marginal Cost

Output of cabinets	Total cost	Marginal cost	Profit, price = $7.50	Profit, price = $10	Profit, price = $25
0	100	—-	–100	–100	–100
100	800	7	–50	200	1,700
250	1,750	6.33	100	750	4,500
350	2,450	7	175	1,050	6,300
430	3,050	7.50	175*	1,250	7,700
490	3,550	8.33	125	1,350	8,700
530	3,950	10	0	1,350*	9,300
550	4,250	15	–125	1,250	9,500
560	4,500	25	–300	1,100	9,500*

Note: The hypothetical data above are for daily production. It is assumed that the variable material cost for each cabinet is a constant $5, that each carpenter is paid $20 per hour, and that the fixed cost from rental of the shop and equipment is $100 per day.

* Indicates the output level where price equals marginal cost.

firm hires enough hours of labor each day so that market price equals marginal cost. As market price rises, the firm increases its output level along its marginal cost curve. Because the firm sets its profit-maximizing output along its marginal cost curve, the firm's marginal cost curve is its supply curve. This is where supply curves come from in competitive markets.

What we have found is that under competitive conditions the firm's marginal cost curve is also its supply curve. A supply curve relates price to quantity supplied, and that is exactly the function of marginal cost. While we could have spared ourselves all this work by just assuming that the firm has an upward-sloping supply curve, it is critical to the discussion below that we acknowledge marginal cost as the basis of a firm's supply curve. Specifically, if firms can reduce their marginal costs by polluting instead of paying for expensive cleanup techniques, then, as we shall see, firms place themselves on an artificially low supply curve, and the result is an inefficiently large volume of goods or services (such as cabinets) traded in the market.

To derive a *market supply curve* from individual firms' supply curves, we simply add up quantity supplied for any given price. This process is called *horizontal summation.* For example, suppose there were 100 firms in the cabinet market we have been talking about, each of which has costs that are just like those shown in Table 4.2. From Table 4.2 we know that a shop's profits are maximized at an output level of 430 cabinets per day when the wholesale market price of a cabinet is $7.50, or 530 cabinets per day at a price of $10, or 560 cabinets per day at a price of $25. If there are 100 such firms supplying the market, then the market supply curve is found by mul-

Table 4.3

Marginal Private, External, and Social Costs

Output of cabinets	1. Marginal private costs	2. Marginal external costs	Marginal social costs (1 + 2)
100	7	3	10
250	6.33	3	9.33
350	7	3	10
430	7.50	3	10.50
490	8.33	3	11.33
530	10	3	13
550	15	3	18
560	25	3	28

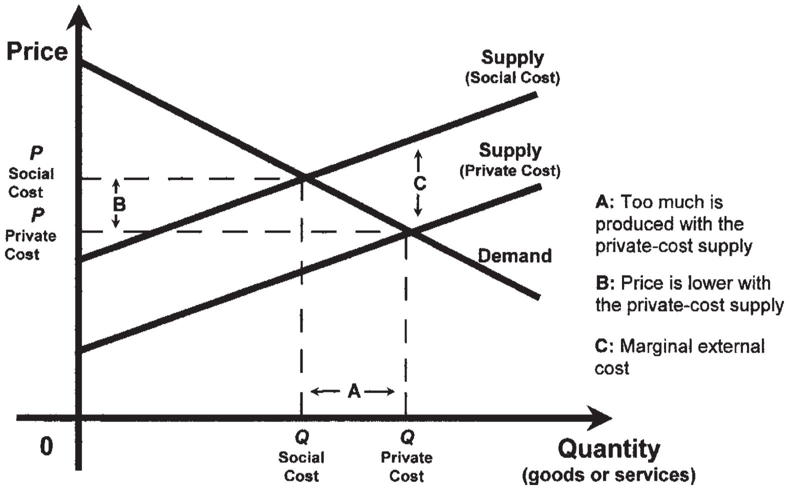
tiplying by 100 the quantity supplied by a single cabinet shop at a given price. Thus, following the cabinet shop example, at a price of $7.50 the market quantity supplied is 43,000, while at a price of $10 the market quantity supplied is 53,000, and at a price of $25 the market quantity supplied is 56,000. Connecting these points in a diagram would yield the market supply curve.

Now suppose that in the process of producing cabinets the shop emits negative externalities. For example, the negative externalities could be volatile petroleum distillates used in an inexpensive stain and preservative. Moreover, assume that a lower-bound estimate of the harms caused by the use of this preservative (the cost of impaired health and damage to the environment, for example) is $3 on a per-cabinet basis. This $3 is an external cost per unit of output, commonly referred to as a *marginal external cost.* Assume that nontoxic, pollution-free wood preservatives are more costly, and so in the absence of regulation (and environmentally concerned consumers), the cabinet-producing firm as a profit maximizer chooses to use the cheaper, more-polluting wood preservative.

Social Cost as the Sum of Private and External Cost

S*ocial cost* refers to a fuller accounting of the costs of production and exchange. Social cost is equal to the sum of *private cost* borne by producers and *external cost* borne by affected members of society in the form of pollution harms. Likewise, *marginal social cost* is the sum of *marginal private cost* and *marginal external cost.* As marginal external cost is a constant $3 in our example, then the marginal social cost is $3 greater than the marginal private cost at any output level. Marginal social costs are derived in this way in Table 4.3. It is assumed here that marginal external cost is constant in order to keep the example simple, but in the real world, marginal external cost might increase or decrease with the quantity produced.

Figure 4.3 **Negative Externalities and Market Failures**



When there are external costs there are two market supply curves. One of these supply curves is operational in the market when firms are allowed to pollute freely. This is the supply curve derived from the firms' private marginal costs. The other supply curve is based on marginal social costs, which takes both private and external costs into account. The supply curve based on marginal social costs will only be operational if firms internalize the external costs of production. These two supply curves are illustrated in Figure 4.3. We will discover in the next section that if firms are allowed to pollute freely, otherwise well-functioning competitive markets fail to allocate resources (cabinets in our example) efficiently. We will also learn that government intervention in the form of a tax equal to marginal external cost will cause firms to internalize external costs and supply along the social-cost supply curve.

Competitive Markets Are Inefficient When There Are Negative Externalities

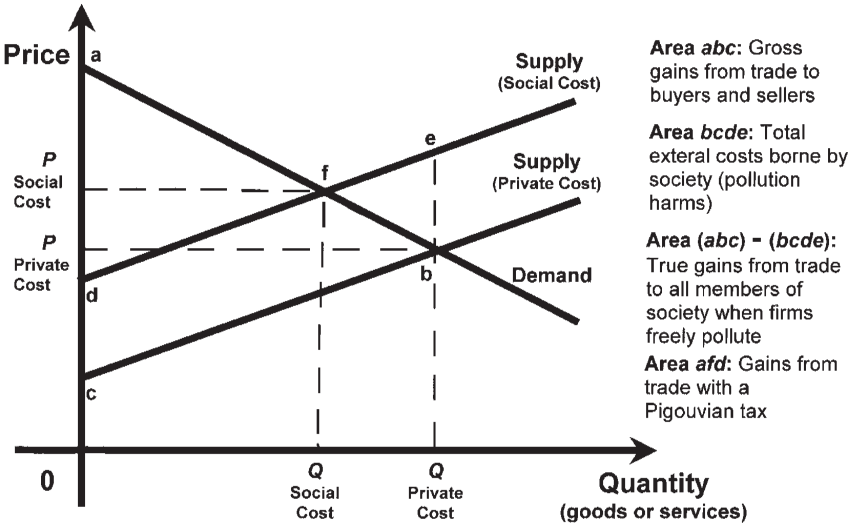
As shown in Figure 4.3, when firms can freely pollute as a by-product of producing a good or service, they supply along a private-cost supply curve rather than a social-cost supply curve. The level of output where the private-cost supply curve crosses the demand curve is the equilibrium level of output when firms are allowed to pollute freely. In contrast, the level of output where the social-cost supply curve crosses the demand curve is the equilibrium level of output when firms are forced to fully internalize all their external costs. Therefore, when firms can freely pollute, firms will supply along the private-cost supply curve, leading to a larger equilibrium quantity of the good or service being produced and sold. This difference in output is denoted by *A* in Figure 4.3, and reflects excess production that occurs in competitive markets where firms are allowed to emit negative externalities freely. The market is not efficiently allocating scarce resources in the market because too much is being produced.

But why is output where the social-cost supply curve crosses the demand curve the efficient level of output? To answer this question we need to think about the gains from trade and external costs. We also need to use some simple geometry. Figure 4.4 will be our guide. Suppose firms are allowed to pollute freely, and so they supply along the private-cost supply curve, yielding an equilibrium price and quantity, as shown in Figure 4.4. The buyers and the sellers receive a gross gain from trade equal to the large triangle *abc* in Figure 4.4. The part of this triangle above the dashed price line is gross consumer surplus, while the portion below the price line is producer surplus. But because firms are freely polluting, there are external costs that we have not yet taken into account. The parallelogram *bcde* in Figure 4.4 gives us the total dollar harms caused by negative externalities. In our simplified example, total external cost is equal to marginal external cost (height *cd* or *be*, which gives us external cost for each cabinet) multiplied by the equilibrium quantity of cabinets produced when firms freely pollute (length 0*Q* along the horizontal axis). After accounting for total external costs, the *true gains from trade to all members of society* when firms freely pollute is area *abc* minus area *bcde*.

Now suppose that firms are forced by regulatory intervention or market reputation to internalize their external costs and supply along the social-cost supply curve. As we will learn in the next section, one way to internalize negative externalities is by way of a tax equal to marginal external cost. When firms supply along the social-cost supply curve, equilibrium output is found at point *f* where the social-cost supply curve crosses the demand curve. Because firms have paid the tax to society, they have (at least in theory) compensated society for their pollution, and thus the firms have internalized the external costs. In this case, the gain from trade when firms fully internalize their external costs is given by the triangle *afd* in Figure 4.4.

Let us return to our question of why output set where the social-cost supply curve crosses the demand curve is the efficient level of output. The reason is that area *afd*, the gains from trade when negative externalities are fully internalized and firms supply along the social-cost supply curve, is larger than area (*abc*) – (*bcde*), the true gains from trade to all members of society when firms freely pollute. In other words, internalizing externalities improves

Figure 4.4 **Why Negative Externalities Make Competitive Markets Inefficient**



the welfare of society. The difference between area *afd* and area (*abc*) – (*bcde*) is the little triangle *bfe*, known in microeconomic theory as *deadweight social loss*, and it represents the resource allocation inefficiency caused by negative externalities. In our simple linear example, deadweight social loss is a triangle with a base equal to the difference in equilibrium output ($Q^{private}$ minus Q^{social}) and a height equal to marginal external cost. An Excel-based simulation is available on the Internet site for this textbook, which you can use to familiarize yourself with the computations showing how output is too large, price is too low, and total surplus is less than the maximum possible when there are negative externalities (ftp://sorrel.humboldt.edu/pub/envecon/module2.xls).

Returning to Figure 4.3, we can also see that allowing firms to pollute freely amounts to society granting these shops a production subsidy on each cabinet produced. Some of this subsidy is passed along to consumers in the form of a lower product price. Whenever firms freely pollute or cause environmental harm in otherwise competitive markets, firms are being subsidized by society and consumers are sharing in this subsidy by way of a lower product price. This subsidy makes it particularly difficult for cleaner alternative technologies to succeed in the marketplace. If one firm were to adopt a more expensive clean technology it would be at a price disadvantage in the marketplace relative to other firms. Unless consumers recognize and reward products made using cleaner technologies, such firms will struggle and fail in the competitive marketplace. As we will see in the next section of the chapter, Pigouvian taxes eliminate this subsidy and enhance market efficiency.

Pigouvian Taxes: Internalizing Negative Externalities

Economist A.C. Pigou suggested that the solution to the problem of negative externalities is to place a tax on firms based on the external costs they generate, thus internalizing the externality and reimbursing society for the external costs. Accordingly, taxes on each unit of output (such as cabinets) equal to marginal external cost are called *Pigouvian taxes.* Therefore, if we tax firms $3 per cabinet in our example, an amount equal to the marginal external cost from producing each cabinet, two things will happen. First, the social-cost supply curve will become operational in the market, as firms are now paying both marginal private cost and marginal external cost. As a consequence, fewer cabinets will be produced, and each cabinet will sell at a higher price. This higher price more completely reflects the social costs of production. Second, profit-maximizing firms will now have an incentive to look for ways to reduce the Pigouvian tax element of their production costs. Of course, one way to do so would be to lobby for removal of the regulation. Assuming that the regulation is stable, however, firms will have an incentive to explore ways to reduce their emissions.

Suppose first that a nontoxic alternative wood preservative is available that costs firms $2 more than the standard toxic alternative, but which eliminates their emissions and thus removes the Pigouvian tax. In this case, the Pigouvian tax will cause firms to switch immediately to the nontoxic alternative and emissions will be eliminated. Now suppose that a nontoxic alternative wood preservative is available that costs firms $4 more than the standard toxic alternative, and which also eliminates their emissions and thus removes the Pigouvian tax. In this case, because the nontoxic alternative is more expensive than the Pigouvian tax, firms will see the tax as a part of the "cost of doing business" and will not adopt the nontoxic alternative. Note that some emissions are eliminated even if firms do not adopt the nontoxic alternative, since market equilibrium output is lower under the Pigouvian tax. Yet even if the nontoxic wood preservative raised costs by more than $3 per cabinet, a Pigouvian tax would encourage research and development to eventually develop a cost-effective way of producing a toxic-free wood preservative.

We can see that Pigouvian taxes change the incentives of both producers and consumers in the market. Of course, taxes are also a way to generate government revenue. Ideally, these revenues would go toward compensating people harmed by pollution and remediating environmental damage caused by the pollution that is being taxed. In practice, there is no guarantee that the political process will generate environmental policies that are consistent in this manner.

Figure 4.3 also illustrates how firms and consumers share in the cost increase when a Pigouvian tax is imposed on producers. If firms were to pay the full social cost of production, price would be *P*(social cost), whereas if firms can avoid the marginal social cost of production, market price is *P*(private cost). If firms were to pay the full social cost of production, consumers would pay an extra [*P*(social cost) – *P*(private cost)] for each cabinet they buy. Because demand for the good is downward sloping, firms cannot pass along all of the Pigouvian tax to consumers; the remainder of the cost increase is retained by the firms in the form of reduced profits. This analysis also illustrates the reverse, namely that when firms can freely pollute in the absence of environmental regulations, consumers share in the cost savings in the form of lower prices. The fewer the number of substitutes available for a product the steeper is the demand curve for the product (such as gasoline), and therefore the larger is the share of the Pigouvian tax passed on to consumers.

In principle, we can argue for government regulatory intervention in the case of pollution externalities on the basis of efficiency alone—namely, resources are not efficiently allocated because too much of the good is produced when externalities remain unresolved. There is also a fairness argument: unless we have a positive externality that requires subsidy, why should society at large have to absorb part of a firm's costs? While the theory of externalities is generally accepted by economists, not all agree that externalities are very large or important. Indeed, if external costs are small and insignificant, then little is lost by simply ignoring them as minor side effects of the wealth generated by markets. Although this may be true in some cases, it does not appear to be universally true at all. For example, as mentioned in chapter 1, recent estimates by the U.S. Environmental Protection Agency (1997) indicate that the Clean Air Act of 1970 created substantial benefits in the form of avoided external costs. In particular, between 1970 and 1990 the Clean Air Act is estimated to have prevented an estimated $22.2 trillion in pollution harms to human health, agriculture, and the environment in constant 1990 dollars. As will be described in greater detail in chapter 6, these benefits were substantially larger than the costs. Thus, externalities can indeed be very large and are worthy of well-designed environmental regulatory policy.

In the real world it is difficult to measure marginal external costs without controversy, and social policy reflects both political expediency and economic efficiency. In chapter 9 we will return to the idea of intervening in markets to mitigate the effects of pollution. In that chapter, we will focus on the more general notion of *pollution taxes* as a tool of environmental policy. Pollution taxes differ from the theoretically ideal Pigouvian tax in that the former may not fully internalize negative externalities, owing to difficulties in measuring marginal external costs, interest group rivalry, and political expediency in the policy-making process. Also in chapter 9 we will discuss the notion of command-and-control regulation as an alternative to taxation. Command-and-control regulation limits the quantity of pollution emissions at the source, and frequently specifies the emissions-control technology to be used. Another alternative to Pigouvian taxes is to let the polluters and those impacted by pollution negotiate with one another and resolve their conflict without government intervention, a process called *Coasian contracting* in honor of economist Ronald Coase. The effectiveness of direct contracting relative to regulation is a policy issue addressed in greater detail in chapter 6.

Summary

- Positive externalities are unpaid-for benefits to society generated as a by-product of production and exchange. When there are important positive externalities, market demand based on the private benefits of buyers understates the full social benefits of the good or service generating the external benefit. Consequently, too little of the good or service generating the positive externality is produced in otherwise well-functioning competitive markets. Subsidies represent a form of policy intervention that can enhance market efficiency. Positive externalities can also affect the supply curve, such as when there are technology spillovers.
- While the legal system is designed to protect property, pollution harms to open-access resources are not protected under law and thus are subject to degradation. The legal system does not function perfectly, of course, and so pollution harms to people, their homes, and other valuable objects that are property do regularly occur. One problem is in determining the source of the pollution when there may be very large numbers of emitters, as is the case with automobile exhaust.
- Negative externalities are uncompensated harms to society generated as a by-product of production and exchange. Profit-maximizing firms have an incentive to transform private costs into negative externalities (external costs) in the absence of regulation or reputation effects. When there are important negative externalities, market supply based on private costs to sellers is too large, leading to too much of the good or service generating the negative externalities being produced in otherwise well-functioning competitive markets. Pigouvian taxes represent a form of policy intervention that can enhance market efficiency.
- In the real world it is difficult to craft Pigouvian taxes owing to (i) practical problems measuring marginal external costs without controversy, and (ii) the influence of rival interest groups and political expediency in the policy-making process.

Review Questions and Problems

1. Suppose that there are 100 identical competitive firms, each of which supplies a quantity where price equals marginal cost. Therefore, if marginal cost is $10 + Q$, each individual firm's supply curve is given by $P = 10 + Q$. Since there are 100 such firms, the market supply curve is $P = 10 + .01Q$. Also assume that market demand is given by $P = 100 - .005Q$. Note that Q refers to the quantity of some good, like shoes.

   a. Solve for the competitive market equilibrium price and quantity.
   b. Suppose now that in part *a* above, firms were freely polluting by emitting marginal external costs equal to a constant \$20 for each unit of output produced. Based on this information we know that each firm's social-cost supply curve is given by $P = 30 + Q$, and the social-cost market supply is given by the function $P = 30 + .01Q$. With demand as given above, solve for the competitive equilibrium when firms must internalize their external costs, such as through a Pigouvian tax.
   c. Based on the correct answers to parts *a* and *b*, calculate the amount by which quantity is too large and price is too low when firms can freely pollute and supply along the private-cost supply curve. Calculate the monetary value of total external cost when firms can freely pollute (the area between the two supply curves up to the quantity traded based on the private-cost supply) and the monetary value of deadweight loss. In what specific way are resources inefficiently allocated when firms can freely pollute?
   d. Suppose that government intervention occurs in the form of a \$20–per-unit Pigouvian tax imposed on polluters. Also suppose that firms can eliminate their emissions of pollution, and thus avoid the Pigouvian tax, by using a different input that increases marginal private costs by \$10 per unit. Will firms pay the Pigouvian tax and continue to pollute, or will they adopt the more expensive clean technology? More challenging: What will be the new market equilibrium price and quantity traded with the more expensive, pollution-free input? Do the benefits of cleanup exceed the cost? How would your answer change if the input increased marginal private costs by \$30?

2. Write a one-page essay in which you explain why, in the absence of government subsidies, competitive markets underproduce goods that feature positive externalities. Be sure to provide an example of a good that generates a positive externality, explain the nature of the external benefits and the two demand curves, and describe how they lead to different market equilibria. Draw and carefully label a diagram to illustrate your arguments.

3. Write a one-page essay in which you explain why, in the absence of government environmental regulation, competitive markets overproduce goods whose production involves the creation of negative externalities. Be sure to provide an example of a good that generates a negative externality, explain the nature of the external costs and the two supply curves, and describe how they lead to different market equilibria. Describe why allowing firms to pollute amounts to a production subsidy, and why this is inefficient, creating an economic motive for government policy intervention. Draw and carefully label a diagram to illustrate your arguments.

4. Describe the various reasons why it might be difficult for government interventions to perfectly resolve positive and negative externalities. Address the problem of measurement as well as the workings of the political process.

Internet Links

Assessing Environmental Costs from Electricity Generation (ftp://ftp.ter.com/pub/g_9402.pdf): Article on external costs by William Desvousges, F. Reed Johnson, and H. Spencer Banzhaf, sponsored by the Research Triangle Institute. This is a PDF file requiring the free Adobe Acrobat Reader.

Environmental Externalities in Electric Power Markets: Acid Rain, Urban Ozone, and Climate Change (http://www.eia.doe.gov/cneaf/pubs_html/rea/feature1.html): An article by John Carlin, sponsored by the U.S. Energy Information Administration.

EPA's Economy and Environment Website (http://www.epa.gov/oppe/eaed/eedhmpg.htm): You can access a wide variety of EPA economic studies, including the benefit/cost analysis of the Clean Air Act cited in the text.

Interactive Negative Externalities Simulation (ftp://sorrel.humboldt.edu/pub/envecon/module2.xls): An Excel-based interactive simulation available on the Internet site for this textbook. You can use this simulation to familiarize yourself with the computations showing how output is too large, price is too low, and total surplus is less than the maximum possible when there are negative externalities. Click "yes" to enable macros. You do not need to know how to use Excel to use this simulation as it is entirely menu-driven.

Negative Externalities Audio Clip (http://www.humboldt.edu/~envecon/audio/1.ram): A brief audio clip of the author describing negative externalities.

Oil Slickers: How Petroleum Benefits at the Taxpayer's Expense http://www.ilsr.org/carbo/costs/truecosttoc.html): An article by Jenny B. Wahl, sponsored by the Institute for Local Self-Reliance. Particularly relevant is section V, on the environmental and health costs of petroleum.

Pollution Taxes (http://www.orcouncil.org/green.html): An easy-to-understand description of pollution taxes by the Oregon Environmental Council.

Private and Common Property Rights (http://encyclo.findlaw.com/lit/2000art.html): Article by Elinor Ostrom in the on-line *Encyclopedia of Law and Economics* that clearly distinguishes private property, common property, open-access regimes, and common-pool resources.

The Common Law: How It Protects the Environment: (http://www.perc.org/ps13.htm): Article by Roger Meiners and Bruce Yandle, sponsored by the Political Economy Research Institute, describing how the common law can be effective in protecting the environment.

The Real Price of Gasoline (http://www.icta.org/projects/trans/): A study produced by the International Center for Technology Assessment on the external costs of gasoline.

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Appendix: A Calculus-Based Derivation of Supply Curves

This appendix is intended for those who have a calculus background but who have not had a microtheory course in which they have derived a competitive firm's supply curve. Supply curves result from firms in competitive markets trying to maximize profits. A firm in a perfectly competitive market is assumed to be relatively small compared to the size of the overall market. As a consequence, an individual firm will take the market price as a fixed parameter and vary its output to maximize its profits. In particular, for a competitive firm, profits are given by

$$\text{Profit} = \text{total revenue } (TR) - \text{total cost } (TC).$$

In the short run, total revenue is simply equal to market price multiplied by the firm's output ($TR = PQ$). Likewise, in the short run, total costs will have a functional form such as

$$TC = a + bQ + cQ^2.$$

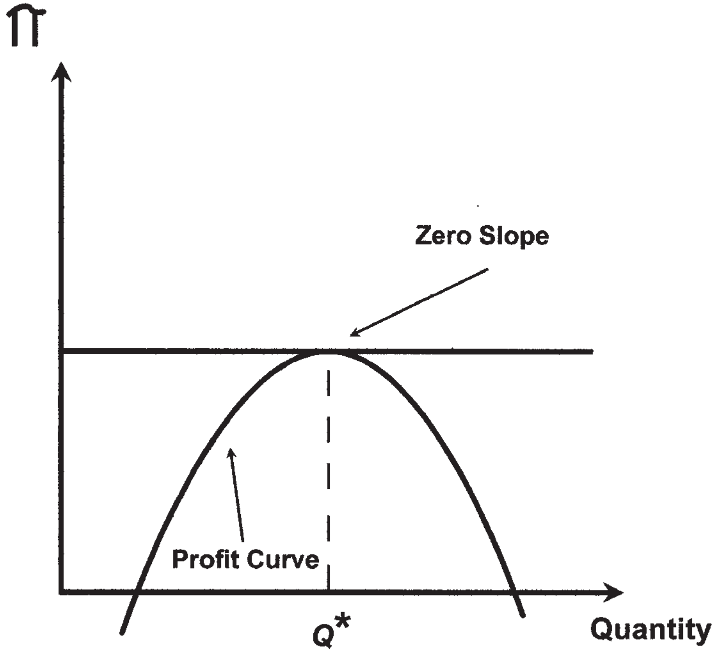
Note that a is the fixed cost of production, like the debt service on a factory, while b and c are coefficients for variable cost $bQ + cQ^2$. Note that variable costs increase with output Q.

Note that marginal cost (MC) in our simple example above is $b + 2cQ$ (the partial derivative of TC with respect to Q), meaning that as Q grows, so does MC. Why? Recall from the text that in the short run a firm will eventually experience congestion of its fixed facilities as it tries to increase output, which means that marginal costs increase with increases in output. Similarly, marginal revenue (MR) is simply P, the market price.

A competitive firm selects its sales quantity, Q, to maximize profit:

$$\text{Profit} = PQ - a - bQ - cQ^2.$$

Figure 4.5 **Profit-Maximizing Output**



Note that, because total revenue is linear, while total cost is convex, there is an output level at which this profit function attains a unique maximum. As shown in Figure 4.5, the profit function first rises, reaches a peak, and then falls. At the peak the profit curve has zero slope, meaning that the derivative of the profit function with regard to Q is equal to zero. At this point, a one-unit increase in Q will generate marginal revenue that is equal to marginal cost. We can use this property of the profit function to determine the profit-maximizing output level Q^* (which is the same Q^* as in Figure 4.1). If you take the partial derivative of the profit function with respect to Q, and set this equation equal to zero, you will find that $P = b + 2cQ$. Because marginal revenue is equal to price for a competitive firm (the derivative of total revenue with respect to Q is equal to P), this equation simply shows us that the profit-maximizing output level occurs where marginal revenue equals marginal cost. As market price changes, the firm sets quantity supplied where market price equals marginal cost. Therefore, a firm's supply curve is its marginal cost curve.

5

The Economics of Natural Resource Systems

Introduction and Overview

Environmental economics is primarily concerned with identifying externalities and evaluating regulatory policies designed to control them. Traditionally, natural resources economics has been concerned with the optimal use and management of natural resource systems. An element of nature is a natural resource when it is directly useful to people, or when human technology can utilize it to form something valuable. For example, petroleum bubbling up through the ground and fouling the soil used to be considered a nuisance to farmers until the development of refining and internal combustion engine technology transformed this material into a valuable natural resource. As will be shown below, the price of a natural resource reflects the relative scarcity of the resource and the availability of substitutes, and acts as a driver for technological innovation. Increasing scarcity will tend to increase the resource's price and promote the production and consumption of substitutes. This process is illustrated by the increased production and consumption of coal and natural gas (and increased research and development spending on alternative energy) following the oil price shocks in the mid-1970s caused by the Organization of Petroleum Exporting Countries (OPEC) oil embargo.

The best methods for managing a given natural resource system depend upon factors such as culture and the physical characteristics of the resource. For example, some natural resource systems—such as oil fields, natural gas fields, coal beds, and other fossil-fuel energy resources—are inherently *nonrenewable.* The question of interest for nonrenewable resource systems has to do with optimal extraction rates over time—should the resource be depleted immediately, very gradually, or not at all? In this chapter we will investigate the conditions required for efficient extraction of a nonrenewable resource over time. Many nonrenewable mineral resources such as iron and aluminum are also recyclable, in which case current primary production creates its own future competition in the form of increased secondary (recycled) supplies. We will review this issue and consider the incentives and the legal treatment of recyclable resource monopolists.

Another class of natural resource system is comprised of the renewable resources associated with the self-regulating elements of life on earth. Issues associated with renewable resources—such as pasturage, forests, groundwater basins, rivers, the air, fisheries, and wildlife populations—include the *maximum sustained yield* that can be harvested from the resource without depleting the productive capacity of the resource system. Private ownership has been suggested as a way of preventing the depletion of commercially valuable resources such as timber and pasturage. Private ownership is not a panacea, however, because private ownership does not resolve harms to aspects of the environment that lack commercial market value. Moreover, resource systems having *common-pool* characteristics, such as the stocks of air, groundwater, stratospheric ozone, and marine fisheries, are difficult to partition as private property. In this chapter we will look at the economics of common-pool resources and the "tragedy of the commons" in detail. We will also examine marine fisheries management as a practical application of the economics of common-pool resources. Additional coverage of common-pool resources from the perspective of local self-governance is provided in chapter 15.

Less obvious but no less important from an economic standpoint are the various *ecosystem services* such as fresh water provided by the hydrological cycle, fertility provided by topsoil, and oxygen provided by plants. Another vital ecosystem service is the *sink capacity* of the biosphere—its capacity to absorb human wastes. Examples of sink functions include the capacity of rivers, wetlands, and other bodies of water to absorb waste, and the capacity of aquatic and terrestrial ecosystems to absorb carbon dioxide generated as a by-product of the burning of fossil fuels. Ecosystem services can be thought of as the flow of benefits that derive from the stock of natural capital. The economics of ecosystem services is a new and emerging area of study that will be briefly surveyed below.

Allocating Nonrenewable Resources

Examples of nonrenewable natural resources include:

- Oil fields
- Natural gas fields

- Coal beds
- Mineral deposits

In fact, nonrenewable resources are in large part synonymous with mineral and fossil-fuel energy resources. The term *nonrenewable* means that the resource system ultimately has a *fixed stock* (fixed size of total "reserves") within the human time frame. Nonrenewable resources can be further divided into two categories:

- Nonrenewable, nonrecyclable (fossil-fuel energy resources)
- Nonrenewable, recyclable (some mineral resources such as iron and aluminum and gold)

Let us begin by considering the nonrecyclable group.

The Industrial Organization of Energy Delivery in the United States

When oil and natural gas were first developed on a large scale in the United States, there was a need to invest in interstate pipelines to transport these fuels from production fields to refineries (oil) or residential and industrial distribution (gas). Many fields were served by only a single pipeline because of economies of scale in pipe diameter, and the common practice was for joint ownership of producing field and pipeline, which then sold the bundle of fuel and transportation service. To prevent monopoly prices being charged on this bundle, the Natural Gas Act of 1938 resulted in producer/pipeline entities being subjected to public utilities–style regulation of prices (i.e., price is used to recover allowed capital expenditures, variable costs, and a "normal" rate of return on capital investment). This pricing system began to break down following the oil price shocks caused by the OPEC oil embargo; administered prices designed for cost recovery could not adapt to rapid price fluctuations following the embargo. At the same time, the development of transportation network interconnectivity increasingly gave end users access to a variety of potentially competitive producers.

The new system that has emerged for natural gas is very similar to that which also exists for oil and which is emerging for electricity as well. In this system, end users purchase the product (gas, oil, or electricity) under competitive market conditions and then separately contract for transportation and delivery services, aspects of which still have monopoly characteristics and so are regulated under public utility principles. As Lyon and Hackett (1993) have shown, this form of partial energy market deregulation makes the problem of transportation system load-balancing in the context of continuous and decentralized injections and withdrawals more complex. There are more transactions and an increased need for system coordination to reduce the potential for negative *network externalities*, which are more likely in partially deregulated systems. Negative network externalities occur when consumer–producer transactions impose harms on overall system function, leading to excess or inadequate pipeline pressure for gas or oil, or the potential for power surges or blackouts in electric transmission and distribution grids.

Evidence for the importance of system coordination and load-balancing in networked energy industries is provided by the California Independent System Operator (ISO). The ISO is an independent entity that has the responsibility for coordinating and balancing the load in California's electric power industry, which features a competitive electric Power Exchange (PX) market and a regulated monopoly power delivery network owned by the major electric utilities. Industrial buyers can purchase directly from power producers in the competitive electricity market, while utility distribution companies purchase electricity in the market for residential buyers. The partially deregulated structure of the California electricity industry has taken the form predicted by Lyon and Hackett (1993). In particular, the distribution network continues to be made up of regulated monopolies owned by the major electric utilities, but in order to accommodate a competitive generation market, partial deregulation has required them to give the ISO control over these networks. Energy providers must schedule injections of electricity onto the grid with the ISO.

The Theory of Dynamically Efficient Nonrenewable Resource Pricing

An important economic problem we now turn to is how to allocate efficiently a fixed stock of resource, such as oil or natural gas, over time. If we were to develop the stock of oil reserves rapidly, current prices would decline, but as the stock is rapidly exhausted, prices in the future will also rapidly increase; yet these high future prices give owners of oil an incentive to reduce current production in order to have oil to sell in the future at these high prices. Recall from chapter 3 that well-functioning competitive markets are efficient in the sense that they maximize total surplus—consumer surplus plus producer surplus. Harold Hotelling (1931) and other economists have derived a similar efficiency criterion for determining the optimal balancing of current and future sales in a competitive natural resource market, called *dynamic efficiency*. Before we consider dynamic efficiency, however, we must first develop some tools for measuring the present value of payments made or received in the future.

Present Discounted Value

Most of us can acknowledge that people would rather have $1,000 today than in the future. Reasons include the ability to spend the money right away and avoid higher future prices due to inflation, or the opportunity to invest the money now and receive interest or dividend income. The higher value placed on receiving $1,000 today rather than in the future reflects the fact that a future payment is *discounted* or diminished when considering its *present value*. To see this in more detail, suppose you are guaranteed to receive $1,000 exactly one year from the present. What is the smallest amount of money that you would accept right now in return for signing over your rights to the $1,000 next year? The answer is your *present discounted value (*PDV*)* of the $1,000.

The formula for determining the PDV of a stream of payments into the future is as follows:

PDV of a stream of future payments = S_i ($ payment, *i* years from the present)/$(1 + r)^i$, $i = 0, 1, 2, \ldots, n$.

Note that Σ_i means "summation over all *i* time periods"; *i* refers to the number of years from the present that a particular payment is received; *r* refers to the *discount rate.* The discount rate is the rate at which the present value of increasingly distant payments shrinks. Interest rates or the average (risk-adjusted) rate of return available from portfolios of stocks are examples of discount rates.

If there is just one payment to be made in a future period that is *k* years from the present, as in our $1,000 example above, then the PDV of the single future payment is found as follows:

PDV of a single future payment = ($ payment, *k* years from the present)/ $(1 + r)^k$.

Continuing our $1,000 example above, suppose that the discount rate is 10 percent. Then using the formula above, $k = 1$, $r = 0.1$, and the PDV of $1,000 to be received next year is $\$1,000/(1.1)^1 = \$909.09$. In other words, if the discount rate is 10 percent, then one is indifferent between $909.09 received today and $1,000 received in one year. Another way to look at this is to note that if you took $909.09 today and invested it in a bond that pays 10 percent interest, then in one year your $909.09 will have grown to be $1,000.

Dynamic Efficiency

A resource market is dynamically efficient when the sum of total surplus (in PDV terms) is maximized over the entire time horizon in which the resource is allocated. We will now consider a very simple example of a competitive market for oil to illustrate how one can solve for the dynamically efficient allocation of the resource in question. We will see that the dynamically efficient allocation is also an equilibrium in that producers have no incentive to reallocate resource sales from one year to the next.

There are a number of assumptions that we need to keep in mind as we work through the analysis. We assume that there is a well-functioning competitive market for the resource in question, and that market participants are fully and completely informed of current and future demand, marginal cost, discount rate, available supplies, and price.

To keep the example simple there will only be two periods in the analysis—the present time, referred to as year 0, and year 1. For the sake of simplicity, we will also assume that the marginal cost of producing oil is constant and equal to \$5 per barrel. As we learned in chapter 4, marginal cost is the basis for the competitive market supply curve. As marginal cost is constant at \$5, the market supply curve for the resource in question is also constant at \$5. Finally, we assume that market demand is the same in each of the two periods.

Let the demand for oil in a given year be given by the following expression:

$$P = 20 - 0.5\,Q.$$

Note that Q refers to quantity of oil in barrels. We will assume that there is a fixed quantity of 40 barrels of oil available for both periods, and that people in this market use a 15 percent discount rate.

To provide a basis for comparison with the dynamically efficient solution, let us first suppose that market participants in year 0 fully ignore the consequences of their actions on year 1 supplies, prices, and profit. Then in year 0 the competitive market equilibrium quantity of oil traded is found at that price (\$5) where supply equals demand:

$$20 - 0.5\,Q = 5.$$

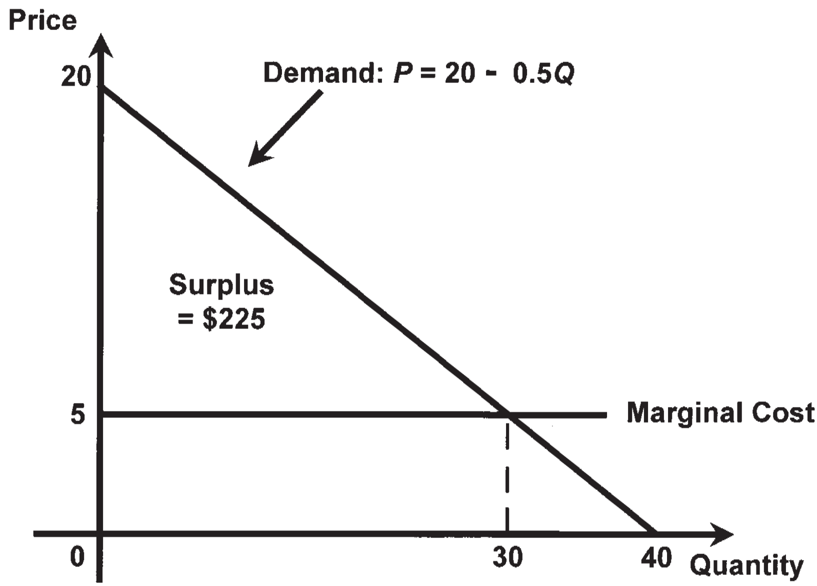
Solving for Q we find that 30 barrels of oil would be traded in year 0. If we now substitute 30 for Q in the demand equation we can confirm that equilibrium price is \$5. Note, however, that we have only left 10 barrels of oil for consumption in year 1.

As we can see in Figure 5.1, if market participants ignore the future, then in year 0 total surplus in this market is:

$$0.5(15 \times 30) = \$225.$$

Because market participants have ignored the future period, there are only 10 barrels of oil available in year 1. With only 10 barrels of oil available, we

Figure 5.1 **Surplus, Year 0**



can determine the price of oil in year 1 by substituting 10 for Q in our demand equation:

$$20 - (0.5 \times 10) = \$15.$$

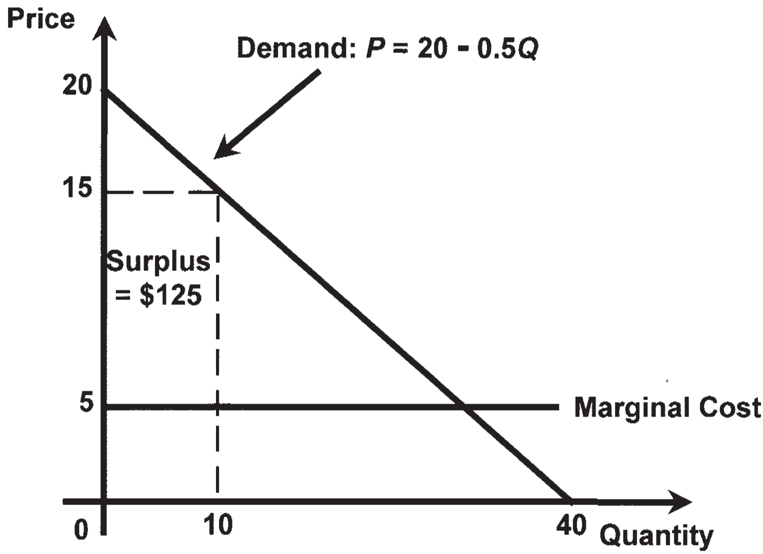
Therefore, total surplus in year 1 is \$125, as illustrated in Figure 5.2.

The sum of total surplus (in PDV terms) over the two time periods is:

$$\$225/(1.15)^0 + \$125/(1.15)^1 = \$333.70.$$

Is the sum of total surplus (in PDV terms) when market participants ignore the future the maximum available? Have we achieved the dynamically efficient allocation of the resource stock? Are we in a dynamic equilibrium? As we will see below, the answer is no. To help build your intuition, suppose that you were a seller of oil in the market above, but you no longer ignored prices and profit in year 1. If you knew that today's price of \$5 would rise to next year's price of \$15, would you want to hold off selling some oil today and save some for next year? The answer is yes. Note that the marginal profit from selling a barrel of oil is (P – MC). The marginal profit from selling a barrel of oil in year 0 is \$0, as price equals marginal cost. If instead you were

Figure 5.2 **Surplus, Year 1**



to save that barrel of oil and sell it in year 1, then the PDV of marginal profit would be $(15 – 5)/(1.15)[1], which equals $8.70. Therefore, profit-maximizing sellers who are fully informed of market conditions in both periods would sell less oil in year 0 and more oil in year 1, which means that we are not in a dynamic equilibrium. We will show below how to find the dynamic equilibrium, and we will also show that this equilibrium is dynamically efficient and maximizes the sum of total surplus (in PDV terms).

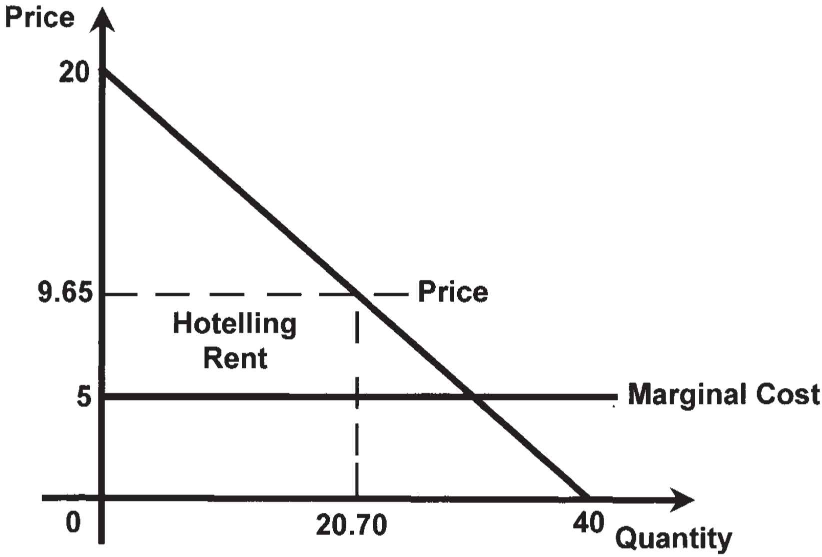
The dynamic equilibrium with full-information is one in which the marginal profit of selling a barrel of oil today is equal to the PDV of marginal profit from selling a barrel of oil next year (and in any future years). Economist Harold Hotelling (1931) developed a rule for finding the dynamically efficient solution to resource allocation problems such as ours. The rule for dynamic efficiency, called *Hotelling's rule*, requires that marginal profit (*P* – *MC*) in year 0 must equal the PDV of (*P* – *MC*) in year 1. Hotelling's rule simply formalizes our intuition that dynamic equilibrium occurs when the marginal profit from selling a unit of the resource is the same today as it is in a future period. As you might expect, if there are more than just two periods, then Hotelling's rule requires that the PDV of (*P* – *MC*) be equal across all time periods in which the resource is to be allocated. When this condition holds, the sum of total surplus (in PDV terms) over all time periods in which the resource is to be allocated will be maximized.

One can solve the dynamic resource allocation problem by using either advanced mathematics or by repeated experiment. As the reader is not assumed to possess advanced mathematics, we will demonstrate the method of repeated experiment. First, let us develop some intuition. We already know that 30 barrels in year 0 and 10 barrels in year 1 is not the answer. Because future payoffs are discounted, do you think that the dynamically efficient solution will lead to (i) a larger share of the resource consumed in year 0 than in year 1, (ii) an equal share of the resource consumed in years 0 and 1, or (iii) a smaller share of the resource consumed in year 0 than in year 1? As future payoffs are discounted relative to the present, society will generally prefer to consume a larger share of the resource in the present, with less saved for the future, as in (i) above. Moreover, the higher the discount rate, the stronger the preference for current—over future—payoffs, and the less that will be saved for the future. Therefore, the dynamically efficient solution to our problem will involve allocating more oil in year 0 than in year 1.

The repeated experiment method simply involves trying different divisions of the resource and testing the allocation using Hotelling's rule. For example, given the intuition we developed above, you might start out trying 22 barrels in year 0 and 18 barrels in year 1. Now, you should test this allocation by computing the PDV of (*P* – *MC*) in the two years to see if they are equal. With 22 barrels in year 0, price in year 0 is $9 and the PDV of (*P* – *MC*) in year 0 is $4. With18 barrels in year 1, price in year 1 is $11 and the PDV of (*P* – *MC*) in year 1 is $5.22. Therefore, an allocation of 22 in year 0 and 18 in year 1 does not meet Hotelling's rule. When Hotelling's rule is not met you should allocate more resource to the period in which the PDV of (*P*–*MC*) is larger, and again check to see whether Hotelling's rule is satisfied. Continue this process until you zero in on a sufficiently precise solution.

In our problem the exact solution involves selling 20.7 barrels of oil in year 0, in which case market price in year 0 is 20 – (.5 × 20.7) = $9.65, and the marginal profit (*P* – *MC*) from selling a barrel of oil sold is $4.65. This allocation is illustrated in Figure 5.3. We would then have 19.3 barrels of oil to sell in year 1 at a price of $10.35. Therefore, you can see that consuming more today and less in the future causes price to rise over time. In year 1, the PDV of (*P* – *MC*) is $5.35/(1.15)^1, or $4.65, which is the same as in year 0, satisfying Hotelling's rule. This is a dynamic equilibrium because sellers have no incentive to shift sales from one year to the next. You should be able to show for yourself that the sum of total surplus (in PDV terms) over the two years is $374.15 in the dynamic equilibrium. With considerably more effort, one can also show that the dynamic equilibrium is also dynamically efficient. Although we will not demonstrate that tedious result here, the Excel simulation provided on the Internet site for this book can be used to demonstrate

Figure 5.3 **Hotelling Rents from Dynamically Optimal Consumption, Year 0**



the dynamic efficiency of Hotelling's rule (ftp://www.sorrel.humboldt.edu/pub/envecon/module3.xls). One can see, however, that the sum of total surplus (in PDV terms) is larger in the dynamic equilibrium than when 30 barrels are allocated to year 0 and 10 to year 1.

This brings us to an important insight. When a resource is abundant, consumption today does not involve an opportunity cost of foregone marginal profit in the future, as there is plenty available for both today and the future. As the resource becomes increasingly scarce, however, consumption today involves an increasingly high opportunity cost of foregone marginal profit in the future. Therefore, the profit created by this form of resource scarcity is called *Hotelling rent* (also known as *resource rent* or by the Ricardian term, *scarcity rent*). Hotelling rent is economic profit that can be earned and can persist in certain natural resource cases due to the fixed supply of the resource. Hotelling rent generated in year 0 by our dynamically efficient solution is illustrated in Figure 5.3. Owing to fixed supply, consumption of a resource unit today has an opportunity cost equal to the present value of the marginal profit from selling the resource in the future. This opportunity cost limits current supply, which in turn elevates current price above marginal cost, creating the rent. Likewise, marginal Hotelling rent is defined to be the marginal profit received from a unit of the scarce resource, ($P – MC$). As a resource becomes increasingly scarce relative to current and future demand, this scarcity is revealed in higher and higher marginal Hotelling rent.

As a final point, note that the discount rate has a powerful impact on the dynamically efficient allocation of the scarce resource. For example, a zero percent discount rate indicates that people are indifferent between a payment today and a payment in the future. If you replaced the 15 percent discount rate with a zero percent discount rate in the example given above, then you should be able to prove to yourself that the dynamically efficient solution results in an equal division of the resource over time. As the discount rate rises, however, people increasingly prefer receiving their gain from trade in the present rather than in the future. Hence, the higher the discount rate, the larger the share of the resource consumed in the present rather than in the future. At the limiting case of a 100 percent discount rate (indicating that people place no value on a future payment, such as those who hold that the world will end after today), then the dynamically efficient solution is to consume all of the resource today. Consequently, the notion of sustaining a resource for future generations relies upon people today having relatively low discount rates. This topic will be addressed in greater detail at the end of chapter 12.

The simple two-period model with stable per-period demand and constant marginal cost yields valuable insights into the way that a scarce resource is efficiently allocated across time by a competitive resource market. Those interested in the more general *N*-period analysis with increasing marginal costs and substitute resources may wish to consult Tietenberg (1996). We will return to the topic of Hotelling rents in chapter 13, where a model of sustainable economic development is presented in which reinvestment of these rents in natural or human-made capital, such as by way of a resource depletion tax, contributes to sustainability.

Allocating Recyclable Resources

Many nonrenewable mineral resources, especially metals, are recyclable. One interesting aspect of recyclable resources is that the *secondary market* of salvaged or recycled resource acts as a substitute for the *primary market* of virgin resource. This is also true to a lesser extent for building materials. Thus, as the resource becomes increasingly scarce, the primary market price rises. This increase in the primary market price in turn leads to an increase in demand for the recycled resource in the secondary market, raising prices there. Higher recycled resource prices in turn increase the quantity of recycled resource supplied, which at least somewhat mitigates the increased scarcity of the primary resource.

An interesting problem for metals cartels and monopolists is in setting production levels and prices for primary resources, knowing that these prices and production levels directly affect future competition from secondary (recycled) resources. Excessive current production of a durable resource or good will increase future used or recycled supplies that act as substitutes for future primary production. Consider the problem of the manufacturer of a durable good such as a textbook. College textbook authors and publishers can mitigate the level of future competition in the used-textbook market by producing new editions of the book. Thus, long before a textbook is fully obsolete, the authors and publishers will find the cheaper used-textbook supplies squeezing out sales of new textbooks, and so will have an incentive to introduce new editions to make the existing stock of used books obsolete. This is an example of planned obsolescence. Now, consider the problem of the producer of metals and other durable resources. In the case of metals, a higher level of current production assures a higher secondary scrap market supply. As the stock of scrap grows, the supply of (new + used) metal grows, driving down price.

This is very similar to the story of Alcoa in the early decades of the twentieth century. Alcoa had about 90 percent of the virgin aluminum market in the United States (smelted from bauxite ore), and competed against recycled material Alcoa had produced in previous years. Because current production creates a negative (pecuniary) externality on future profits, the optimal amount of metal to supply in the current year reflects not only the current year's profits but also the present value of all impacts on (forecasted) future profits. Gaskins (1974) was able to show that in this circumstance, Alcoa had an incentive to produce less than the optimal monopoly output of primary aluminum in order to mitigate future secondary aluminum competition. Alcoa was found guilty of monopolization of the U.S. aluminum market in 1945. Judge Learned Hand argued in the decision that, "The competition of 'secondary' must therefore be disregarded, as soon as we consider the position of 'Alcoa' over a period of years: it was as much within 'Alcoa's' control as was the production of the 'virgin' from which it had been derived" (in Gaskins 1974, p. 254).

Even though Alcoa did not have a full monopoly in the (new + scrap) aluminum market, Judge Hand argued that Alcoa was able to use its monopoly in the virgin aluminum market to control the supplies of its scrap supplier rivals, and thus exert market power in the (new + scrap) market.

Economists such as Milton Friedman have commented on the Alcoa decision by pointing out that the secondary market would eventually have curtailed Alcoa's monopoly in the primary market. Yet Gaskins (1974) found that if aluminum demand is growing, as has been the case, then demand growth almost totally mitigates the pro-competitive effect of the secondary market, which supports Judge Hand's decision.

Allocating Renewable Resources

Unlike nonrenewable resources such as minerals, renewable resources are a part of the self-regulating process of the living planet. Removing some trees, fish, groundwater, forage, or dissolved oxygen in a river will not result in permanent destruction of the resource stock. Renewable resources can be depleted, however, if use exceeds the *maximum sustainable yield* over extended periods of time. Substantial work has been done on establishing maximum sustained yield from various renewable resource stocks, the results of which underlie disciplines such as fisheries and forest management. The notion underlying maximum sustained yield is to identify the largest harvest rate (a "flow" variable) that can be sustained indefinitely from the existing resource stock. A complicating factor is that resources on the living planet are not independent of one another—harvest of one affects availability of another. Thus, a harvest rate consistent with maximum sustained yield of one resource (say, timber) can affect the level of the stock of another resource (say, a fishery or wildlife).

This challenge of balancing multiple interdependent resource uses and maximum sustained yield of a renewable resource is illustrated by the United States Forest Service (USFS). The USFS is a federal agency created by the Organic Act of 1897 and charged with managing federally owned lands, largely forested, for multiple uses. Gifford Pinchot, an early leader of the USFS, gave direction to USFS employees by arguing that multiple use meant that all resources occurring on national forest lands—wilderness/recreation, watershed, timber, wildlife—had an equal standing. Prior to the 1950s, it was less common for timber harvesting to adversely affect the other resources occurring on the national forest lands. During the 1950s, however, the amount of timber harvested nationally more than doubled, as did recreational visitation. Thus, conflicts began to arise between those who thought that timber harvest should be the primary product of the national forests and those who believed that protection of other resource values was the highest priority.

In 1960, the Multiple-Use Sustained Yield Act formally stated as law Pinchot's argument that all resource values had equal standing and arose in part because of negative public reaction to the unconstrained timber harvesting being conducted by USFS personnel. Thus ended the era of the "traditional Forest Service" largely insulated from the public and the political process (Keter 1996). Respect for nontimber resource values was further strengthened by passage of a series of laws during the 1960s and early 1970s.

The Wilderness Act of 1964 allows Congress and the president to grant formal wilderness protection under federal law to certain tracts of federal land and was a landmark law in recognizing nontimber resource values. The National Environmental Policy Act of 1970 formally requires the USFS and other agencies to conduct environmental impact analyses and to provide for public participation. The Endangered Species Act of 1973 requires that projects such as logging in the national forests be contingent on there being no adverse impact on any species listed as endangered or threatened and requires mitigation for adverse impacts to these species. The Resource Planning Act of 1974 requires the USFS and similar agencies to propose long-term objectives and to construct long-term resource plans consistent with these objectives. Concerns about the harms caused by clear-cutting led to the passage of the National Forest Management Act of 1976, which requires the USFS to create a forest plan for each national forest. This plan provides key direction to timber harvest volumes, methods, and locations, and explicitly requires a plan for managing nontimber resources. Forest plans are contentious and allow for public comment and appeal, and so they take a great deal of time to develop, but nearly all projects are now open to public review and appeal.

According to the U.S. Forest Service (1995), \$130.7 billion in gross domestic product will be created by national forests in the year 2000. Of that, \$97.8 billion derives from recreation, plus \$12.9 billion from fish and wildlife benefits. The combined recreational and fish/wildlife values account for 85 percent of the total economic value generated by U.S. national forests. Only \$3.5 billion will be generated by timber harvest. Similarly, of the estimated 3.3 million jobs directly or indirectly generated by activity in the U.S. national forests for the year 2000, recreation and fish/wildlife will account for 87.7 percent of the total. Recreational visitor-days totaled 730 million in 1993, nearly a quarter of which occurred in California, and overall recreational use is projected to increase 63 percent by 2045. The budget process is still largely driven by timber harvesting, however; while recreation accounts for 75 percent of the economic benefits generated by national forests, only 21 percent of the Forest Service budget goes to support this activity.

Renewable Resources Case Study: The Economics of Marine Capture Fisheries

Fishery resources are the only wildlife resource still commercially harvested on a large scale. Worldwide, it is estimated that 200 million people depend on fishing for their livelihoods. Because fishing does not require land ownership, and is often open-access, it becomes the employment area of last resort for many people in low-income countries. It was once thought impossible for human harvest rates to exceed the rate of reproduction in marine and other large-scale fisheries, yet many wild fishery stocks around the globe are in substantial decline. The United Nations Food and Agriculture Organization (UNFAO) reports that worldwide landings from marine "capture" fisheries (as distinguished from aquaculture) leveled off during the 1990s at approximately 86 million metric tons (UNFAO 1998). The UNFAO reports that an estimated 44 percent of the world's marine fisheries are fully exploited. They estimate that 16 percent are overfished and have an increasing likelihood of decreasing catches if remedial action is not undertaken to reduce or suppress overfishing. The UNFAO (1998) also reports that another 6 percent appear to have been depleted due to uncontrolled and excessive fishing pressure, and 3 percent seem to be recovering slowly. The effect has been most drastic in the Atlantic Ocean fisheries, as illustrated in Table 5.1.

As Table 5.1 indicates, many fishery regions around the world are overfished. The Atlantic Ocean has been particularly hit hard. The Grand Banks and Georges Bank fisheries in the northwest Atlantic had once been some of the world's most productive fisheries, and yet are now essentially closed following their collapse. The formerly dominant species of groundfish—flounder, cod, haddock, and hake—have been fished down to a small fraction of their previous abundance and are considered commercially extinct. The Georges Bank codfish catch peaked at more than 60,000 metric tons in 1983 and declined to nearly 20,000 metric tons by 1994. Even harder hit was the Georges Bank haddock and yellowtail flounder fisheries, where catches declined by more than 80 percent between the 1960s and 1993. Haddock were declared commercially extinct in the Gulf of Maine in 1995. The Canadian government closed its Atlantic cod fisheries in 1992, and in 1993 it extended the closure indefinitely (Ruitenbeek 1996). The numbers of sexually mature cod, haddock, and flounder stand at approximately one-fifth the level necessary to sustain their future populations. The Atlantic cod catch in the northwest Atlantic peaked in the 1960s at about 1.43 million metric tons annually, declined to 644,000 metric tons annually in the 1980s, and collapsed to only 48,000 metric tons in 1994. Similarly, the 1997 catch of cod, hake, and haddock in the northwest Atlantic was only 16.5 percent of the 1990 catch (FAOSTAT database). The National Marine Fisheries Service reports that, in 1965, cod, haddock, hake, and flounder made up more than 70 percent of the common fishes in the Gulf of Maine. By 1992, dogfish and skate (less desirable species of fish) made up more than 75 percent of the common fish in these waters. The collapse of the northwest Atlantic groundfish fishery has left thousands of people out of work. The Massachusetts Groundfish Task Force found that overfishing resulted in an annual $350 million loss in revenue and the elimination of 14,000 jobs.

Table 5.1

State of the World's Marine Capture Fisheries

Fishing region	Estimated year that total landings potential was reached	Potential–actual landings, metric tons (1990–94)	Status	Reliability of estimate
East Central Atlantic	1984	1	Overfished	Reliable
Northeast Atlantic	1983	2	Overfished	Less reliable
Northwest Atlantic	1971	1	Overfished	Reliable
Southeast Atlantic	1978	2	Overfished	Reliable
Southwest Atlantic	1997	–1	Increasing landings	Unreliable
West Central Atlantic	1987	0	Overfished	Less reliable
East Indian	2037	7	Increasing landings	Unreliable
West Indian	2051	9	Increasing landings	Unreliable
Mediterranean and Black Seas	?	0	Fully exploited	Unreliable
East Central Pacific	1988	1	Overfished	Reliable
Northeast Pacific	1990	1	Overfished	Less reliable
Northwest Pacific	1998	2	Increasing landings	Reliable
Southeast Pacific	2001	14	Increasing landings	Less reliable
Southwest Pacific	1991	0	Overfished	Reliable
West Central Pacific	2003	3	Increasing landings	Reliable
Antarctica	1980	0.1	Overfished	Reliable
All areas (only most reliable data)	1999	–1		
All areas, all data	Not reported	42		

Source: FAO Fisheries Circular No. 920 FIRM/C920, "Review of the State of World Fishery Resources: Marine Fisheries." Rome, 1997.

Sardine, anchoveta, and herring fisheries have had similar experiences with human mismanagement. As reported by McEvoy (1986) in his history of California fisheries, in the 1932–33 fishing season the West Coast sardine fishery reached its estimated maximum sustainable yield of approximately 250,000 to 300,000 tons. The majority of the sardine fishery occurred in California waters, and there were 570 trollers fishing for sardine off the California coast in 1936. By the 1936–37 fishing season, the sardine catch had increased to nearly 800,000 tons. Most sardines in this period were reduced into fishmeal and fed to poultry and livestock, or used as fertilizer. Despite any sort of conservation measures, the sardine catch managed to hold at between 500,000 and 600,000 tons through the 1945–46 season. By 1947, the number of trolling vessels in California waters nearly doubled to 1,100. Having mined the fishery stock, and thus nearly eliminating reproduction and new recruitment into the fishery, sardines became commercially extinct in the Pacific Northwest by the late-1940s. Vessels from those northerly waters then came south to seek sardines in southern California waters where there were still schools of fish to be found, thus adding to the increased quantity of fishing effort that was already being applied to the California sardine fishery. Spawning failed in 1949 and 1950, and by the early 1950s the entire West Coast catch fell to slightly less than 15,000 tons. With high demand for sardines as feedstock for fertilizer, pressure turned to the Peruvian anchoveta fishery, which, like the California sardine fishery went through a brief boom followed by collapse in the early 1970s. Following the same trend, the North Sea herring catch peaked at more than 1 million tons in 1966–67; by 1977 the catch was less than 40,000 tons, and a ban was placed on harvest in 1978.

In April 1994, the U.S. National Academy of Sciences (NAS) concluded that excessive fishery harvest had caused drastic reductions in many of the preferred species of edible fish. Moreover, the NAS reported that changes in the composition and abundance of marine flora and fauna had been extensive enough to endanger the functioning of marine ecosystems. Although the NAS recognized that fishing was only one of a number of different negative human impacts on the marine environment, overfishing was considered the most important single impact. Similarly, the FAO has concluded that substantial damage has occurred to the marine environment, and to the economies that depend on the fishery resource.

Marine Fisheries Management

The failure of effective management of the world's marine capture fisheries is attributable to a number of different factors. Many marine capture fisheries were open-access resources when they were initially exploited, and thus had few if any limits on harvest. The biomechanics of fishery populations are not known with certainty, and so biologists cannot always get a precise count on the number of fish available. As a consequence, it may not be possible to know that a fishery is imperiled until it has already been substantially destroyed. Disagreements between fishery biologists and fishers regarding the abundance of fishery stocks can make it difficult to agree on appropriate management tools. These conflicts can be especially sharp in mixed-stock fisheries in which depleted and abundant species occur on the same fishing grounds and are caught with the same gear, and restrictive management for the depleted stocks necessarily binds the harvest of more abundant species. For example, depleted wild salmon mix with more abundant hatchery salmon, and restrictive management of depleted wild salmon limits the harvest of the more abundant hatchery salmon. Fishery management agencies are lobbied heavily by fishers, and it can be politically difficult for managers to reduce catch in order to recover overfished stocks when doing so imperils the short-term economic needs of the fishers. Moreover, as we will discuss below, once management systems are put into place they can lead to harmful unintended consequences.

Traditional regulatory schemes used in marine capture fisheries in the United States and elsewhere include output controls, technical measures, and input controls. Examples of output controls include total allowable catch (TAC) for the fishery and trip or bag limits on vessel landings. Examples of technical measures include restrictions on fish size and sex. Examples of input controls on effort, the oldest type of fishery management tool, include gear restrictions, vessel licenses, and seasonal restrictions. Most fisheries are managed using a combination of such measures. In many cases, these regulatory tactics have proved to be ineffectual in sustaining fishery stocks and have led to a number of harmful unintended consequences for both fishers and consumers. Consider, for example, the historical management practice used for Alaskan halibut and sablefish, which involved establishment of a TAC, gear restrictions, and seasonal restrictions. This set of management tools was typical of many other fisheries. Because fishers do not have a property right to a share of the TAC, they respond to limited seasons by acquiring more gear and larger vessels so that they can capture more fish in a shorter period of time during the open season. The result is an intense race for fish, or *derby*, which in turn may require regulators to further reduce the season openings. The central Gulf of Alaska halibut fishery, which has accounted for between a third and a half of the total U.S. and Canadian catch since 1977, offers an illustrative example of induced derby effects. The halibut season length fell from over 150 days in the early 1970s to two to three days in the early 1990s, while the total catch approximately tripled (National Research Council 1999).

Derby fisheries suffer from a number of problems. First, derbies create an incentive for fishers to acquire larger vessels and more gear than they would otherwise need, thus leading to overcapitalization. Second, the large pulse of fish landings, followed by long periods of inactivity, requires that the fish be frozen and sold throughout the year, yielding a lower-quality product than live or fresh fish. Third, the race for fish can induce fishing in hazardous seas and unnecessary loss of life. In their Census of Fatal Occupational Injuries, the Bureau of Labor Statistics (BLS) lists commercial fishing as the single most deadly occupation in the United States. The BLS reports that in the five-year period between 1992 and 1996 there were 140 fatalities per 100,000 fishers in the United States, compared to the national average of 5 fatalities per 100,000 for all occupations.

The FAO (UNFAO 1998) estimates that between 1970 and 1990 the world's (covered-deck) fishing fleet doubled in number, and then stabilized at approximately 1.2 million. Much of this increase is attributable to rapid growth of the Chinese fishing fleet. Unfortunately, these numbers mask increases in vessel size, gear, and fishing technology that have enlarged the overall fishing capacity of individual vessels. The race for fish that occurs under open access and under limited season openings is one reason for the growth in fishing capacity in the world's marine capture fisheries. Subsidies designed to build larger domestic fishing fleets are another reason for this growth in capacity. The FAO estimates that the world's *fishing effort* (deployment of fishing inputs) needs to be reduced by at least 30 percent in order to rebuild depleted stocks. The implication is that there is excess fishing capacity and overcapitalization. Overcapitalized fishers loaded down with debt can put enormous political pressure on policymakers setting catch limits.

There are practical difficulties involved with reducing excess fishing capacity. One practical difficulty is that of measurement. Some gear and vessels can be deployed in different fisheries, which makes it difficult to attribute capacity by fishery. Moreover, attempts at reducing fishing capacity in one fishery can result in vessels and gear shifting to another fishery. For example, efforts made by some developed countries to reduce fishing capacity have led to the relocation of vessels to the fisheries of other (usually developing and least developed) countries. This does not constitute a reduction in capacity on a global scale. Moreover, the open-access nature of high seas fisheries creates a particularly difficult situation with respect to the control of fishing capacity. In the 1982 United Nations Convention on the Law of the Sea, in particular, the issue of fishing capacity is largely ignored (UNFAO 1998). As the FAO (UNFAO 1990) observes:

> The relative failure of international management to establish sustainable fisheries in many areas, despite the high quality of the research base sometimes provided, is clearly demonstrated by the dwindling resources, excessive catching capacity [number and size of boats and gear], uncontrolled transfers of fishing effort between resources and oceans, and depletion of many highly valuable resources. . . . The fact that uncontrolled development of fishing effort leads to disaster has now been widely acknowledged in the scientific literature, and by high level fisheries management and development authorities.

As we shall see in the next section of the chapter, there are a number of new alternative management schemes that address excess capacity, the race for fish, and the overfished status of many marine capture fisheries.

Individual Quotas and Other Alternative Management Regimes for Marine Capture Fisheries

A key problem with both open-access fisheries and traditional fishery management tools is that fishers do not have any property rights to a share of the available fishery stock prior to capture. Because fishers do not have a property right to fish until capture, the harvest by one vessel imposes a *rule of capture* externality on all others by reducing the remaining stock of fish. When the rule of capture externality is operating, fishers have an incentive to overcapitalize in vessel, crew, and gear (Casey et al. 1995). We have also seen that the rule of capture externality promotes a race for fish that leads to diminished product quality and increased fishing hazards. A number of alternative management regimes have recently been implemented to address some or all of these deficiencies of traditional management. Some of the more prominent examples are summarized in Table 5.2 and will be discussed below.

Individual quotas (IQs) have been implemented in an increasing number of fisheries around the world. The IQs assign a share of the total allowable catch (TAC) to individual fishers (IFQs), vessels (IVQs), or communities (CFQs). Those who hold quota shares own a share of the TAC. Therefore, the fishing season does not end until all quota shares are filled, subject to biological constraints. By assigning rights prior to capture, IQs eliminate the rule of capture externality. As a result, derby conditions and the incentive for overcapitalization are either substantially reduced or eliminated. Reducing overcapitalization increases the *economic efficiency* of the fishing industry by reducing the total cost of harvesting a given quantity of fish. The IQs can also be transferable or tradable, which can introduce further gains in economic efficiency. When IQs are tradable in a competitive market setting, economic theory suggests that quota will flow to its highest-valued use. This is particularly important in overcapitalized and depleted fisheries in which quota shares are too small to allow for economically efficient and profitable vessel operation. In this case, tradable quota shares will tend to be concentrated on a subset of the original fishing fleet that can operate efficiently and profitably. Those who exit the fishery can at least receive the value of their quota share. An IQ operating on an isolated fishery undergoing consolidation can result in vessels simply being redeployed in some other less-regulated fishery, which reduces the global benefits of a tradable IQ.

There is some evidence that IQs have increased economic efficiency and have eliminated the problems due to the race for fish, though relatively few studies have been done to date. In the Atlantic surf clam/ocean quahog fishery, imposition of an IQ system in late 1990 resulted in a decrease in excess capacity and a consequent increase in economic efficiency (National Re-

Table 5.2

Some Alternative Management Regimes for Marine Capture Fisheries

Management regime	Purpose	How it works	Examples	Discussion
Individual Fishing Quota (IFQ)	Eliminate derby, reduce overcapitalization, increase economic efficiency	Quota shares to total allowable catch (TAC) allocated to individual fishers; may be transferable	Alaskan halibut and sablefish, Australian bluefin tuna, Icelandic herring and cod, New Zealand fisheries, U.S. Atlantic surf clam and ocean quahogs	Establishment of initial quota shares may be contentious; must be feasible to set TAC and monitor landings; concentration of ownership is an issue
Individual Vessel Quota (IVQ)	Eliminate derby, reduce overcapitalization, increase efficiency	Similar to IFQ except that shares are allocated among registered instead of individuals	British Columbian halibut, sablefish, and groundfish; Norwegian fisheries	Similar to IFQ
Community Fishing Quota (CFQ)	Promote community cohesiveness and other goals	Quota shares to TAC allocated to a community defined by geography, cultural identity, or some other factor(s)	Chatham Islands and Maori communities in New Zealand; Sambro, Nova Scotia	Like the closely related community development quota system, CFQ's promote community cohesion
Effort Quota (EQ)	Reduce effort and increase economic efficiency	Quota shares to effort, including inputs such as crustacean traps, or time at sea; may be transferable	Washington Dungeness crab pot licenses, Florida spiny lobster crab trap certificates, scallop fleet days-at-sea limits	Only effective in controlling total catch if there are no substitutes for the restricted input, and input productivity is predictable and stable

Sources: National Research Council. 1999. *Sharing the Fish: Toward a National Policy on Individual Fishing Quotas*. Washington, DC: National Academy Press. Washington Fish and Wildlife Commission. Organization for Economic Cooperation and Development. 1997. *Evaluating Economic Instruments for Environmental Policy*. Paris: OECD.

search Council 1999; Adelaja et al. 1998). The number of vessels working the fishery declined by at least one-half. Likewise, the imposition of IQs on the Icelandic herring fishery increased economic efficiency, reduced the number of vessels from 200 to 29, and increased the profitability of fishing firms (National Research Council 1999). Along these same lines the OECD (1997) reports that imposition of IQs in Australia's bluefin tuna fishery resulted in a 70 percent reduction in vessel numbers and an estimated fourfold increase in Hotelling rent. Evidence shows that IQs in New Zealand have reduced overcapitalization (Clark 1993). IQs have also eased the derby characteristic of some New Zealand fisheries and have resulted in increased export sales of more valuable live product such as rock lobster. Similarly, the imposition of IQs in British Columbia's halibut fishery resulted in the percentage of halibut landings sold as a higher-valued fresh product to increase from 42 percent to 94 percent, thereby raising ex-vessel prices and profitability (Casey et al. 1995).

Because an IQ grants the owner a right to catch a fixed percentage of TAC, the price of an IQ should reflect the present discounted value of the expected flow of Hotelling rents from the quota. Therefore, rising quota share prices indicates an increase in Hotelling rents, which can be attributable to increasing economic efficiency and the sustainable management of the fishery. For example, the price for renting Icelandic cod quota increased from \$0.05 to \$0.09 per kilogram in 1984 to approximately \$1 per kilogram in 1994. Similarly, the price of quota shares in many of New Zealand's fisheries has increased. For example, the average sales price of abalone quota increased from NZ\$50,000 per metric ton in 1991 to approximately NZ\$190,000 per metric ton in 1994 (National Research Council 1999).

A number of issues can make IQs difficult to implement. First, it must be possible to establish a TAC on the fishery, which from a biological point of view may be difficult. Moreover, it must be feasible to monitor landings to prevent cheating on quota shares. Second, quota shares must be allocated to individuals, vessels, or communities, and the initial quota allocation can be contentious. A common practice is to allocate initial quota shares based on historical landings. If conflict already exists on the fishery owing to significant capacity differences in vessels or to recent entry by vessels displaced from other fisheries, this conflict is likely to be manifested in initial quota assignments. Conflict can also occur over whether processors are to be allocated quota shares. Moreover, if individual quotas are being allocated, there is an issue over whether crew members should receive quota shares, which introduces further problems due to poor documentation of crew member tenure on the fishery. Third, a decision must be made about whether IQs are to be tradable. If IQs are to be tradable, then a determination must be made regarding who is allowed to purchase quota shares, and whether there is to be an upper limit on quota holdings by an individual, vessel, or community. Limits on quota shares were not established on the IQs for the Atlantic surf clam/ocean quahog fishery, which led to some degree of ownership concentration and concerns about market power and rapid declines in total employment (National Research Council 1999). Fourth, some see IQ systems as a giveaway of public resources to private individuals, and so a decision must be made over whether some sort of auction or tax should be used to reclaim Hotelling rent from fisheries, and to fund monitoring and enforcement.

Effort quotas have been used to limit effort and reduce overcapitalization in fisheries. Most of the effort quotas used in the United States have been trap certificate programs in pot fisheries for crustaceans such as Dungeness crab and spiny lobster. In the case of trap certificates, a total number of traps for the fishery is established, and trap quota shares or certificates are usually assigned to fishers based on individual landings history in the fishery. As with IQs, trap certificates can be tradable. Effort quotas have also been used for Atlantic groundfish and scallops through fleetwide "days-at-sea" limitations (National Research Council 1999). Whereas effort quotas can reduce overcapitalization and to some degree temporally spread landings, they do not establish rights to fish prior to capture and thus do not resolve all of the negative aspects of derby fisheries.

Unfortunately, even less information is available on the performance of effort quotas such as trap certificate programs than on IQs. A trap certificate program was instituted in 1992 for the Florida spiny lobster fishery. The purpose of the program was to stabilize the fishery and increase yield per trap by reducing the total number of traps. As a result of the trap certificate program, the number of spiny lobster traps decreased by 42 percent, from the 940,000 reported in 1991–92 prior to the certificate program, to 544,000 in the 1998–99 season (Milon et al. 1998). They also report an increasing, though still small, degree of concentration in the spiny lobster fishing industry. As a result of the reduction in traps, the average price of individual trap certificates sold to nonfamily members rose from about $5 in 1994 to about $20 in 1998 (Milon et al. 1998).

Aquaculture

Although most of the world's marine capture fisheries have reached full exploitation, aquaculture continues to grow in both absolute levels and as a percentage of total fish production. The material below is drawn from the FAO (UNFAO 1998), and most recent available data are for 1997. In 1990, aquaculture represented 13 percent of total fish production; by 1997 this percentage had increased to 23.17 percent.

Aquaculture production increased from 13 million metric tons in 1990 to slightly over 28 million metric tons in 1997. Approximately one-half of the salmon and one-third of the shrimp consumed in 1996 were produced by aquaculture. Freshwater aquaculture production represents approximately 60 percent of total aquaculture production. While freshwater aquaculture is dominated by finfish production such as carp, marine aquaculture is dominated by shellfish. China produces nearly 68 percent of total world aquaculture production, and 82 percent of world aquaculture production occurs in lower-income food-deficit countries. High-value aquaculture species include giant tiger prawns, Pacific cupped oysters, various carp, and Atlantic salmon.

Though aquaculture is an important source of food in food-deficit nations, in some cases aquaculture can harm wild fishery stocks. For example, some shrimp farmers engage in large-scale "biomass fishing"—fine-mesh net fishing that catches large numbers of the juveniles from wild fishery stocks. Weber (1995) has argued that the construction of pens for coastal fish farms accounts for one-half of the decline in the world's mangrove ecosystems, which are essential nurseries for many species of fish and natural water filtration systems. For example, Nixon (1996) reports that approximately 75 percent of the mangrove acreage existing in the Philippines in the 1920s has been removed, with the trees harvested for lumber and the sites commonly transformed into shrimp farms. Safina (1994) reports that farming of groupers, milkfish, and eels requires that hatchlings be captured from wild stocks because they cannot be bred in captivity, which puts further pressure on wild stocks. The density of fish in aquaculture facilities increases the potential for diseases to spread, which increases the risk of lost production to operators and creates the potential for diseases to spread to wild stocks.

Allocating Common-Pool Resources

As we learned in the marine capture fisheries case study above, many natural resource systems are not partitioned by private property rights. These resources may be held as state property or common property (among a defined user group), or they may simply be open-access. This ownership status might be based on tradition or culture, or because certain resource stocks such as air, groundwater, or open-ocean fisheries are fugitive resources that cannot effectively be partitioned and privately owned.

When a resource stock is not partitioned by private property rights, there is potential for rivalry among those who *appropriate* (harvest resource units) from the resource stock. In the fishery case study above, we developed the idea of the *rule of capture* externality. The rule of capture externality is more generally known as an *appropriation externality*, which occurs because resource units appropriated by one subtract from what is available for others. Thus, we say that a common-pool resource (CPR) has the following general characteristics:

- It is difficult to exclude multiple individuals from appropriating from the resource stock, such as is the case when the resource stock is not partitioned by a well-defined and enforced private property rights regime.
- The resource features rivalry in consumption, or subtractability, meaning that resource units appropriated by one party subtract from what is available to others.

A *pure public good* differs from a CPR in that it lacks rivalry in consumption. For example, public television and radio broadcasts do not feature rivalry in consumption because one person's reception does not usually impair the ability of someone else to receive the same broadcast.

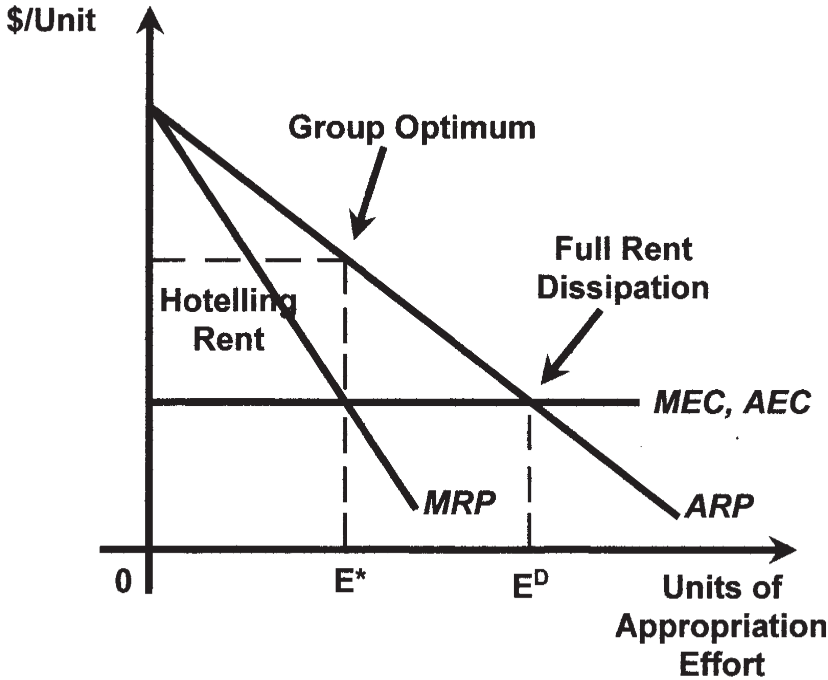
As Gordon (1954) and others since then have shown, in the absence of effective *institutions* (rule structures) that limit appropriation from a CPR, people will over-appropriate from the CPR relative to the level of appropriation that would be efficient for the group as a whole. For example, if a commercially valuable CPR could be transformed into a privately owned renewable resource, then the resource owner would select the dynamically efficient appropriation level each year. As with nonrenewable resources described earlier in the chapter, the efficient level of appropriation sustains the resource and generates the largest possible present discounted value of Hotelling rent.

Gordon constructed a simple model of a commercially valuable CPR under open-access conditions to illustrate the problems associated with appropriation externalities. Gordon's model helps us understand the economics of CPR depletion, such as in many of the world's marine capture fisheries. The diagram for Gordon's model differs from the standard supply-and-demand diagrams we have worked with so far. In Gordon's model, the problem is to find the optimal amount of effort input E instead of the optimal quantity of output Q. As we learned in the fisheries case study in the section above, appropriation effort refers to inputs such as capital and labor that are applied to harvesting resource units from the CPR. To keep the example simple, assume that the market price of the resource being harvested is not affected by the amount of effort applied to the fishery. For the same reason we assume that *marginal effort cost* (MEC) and *average effort cost* (AEC) are constant. The MEC is the increase in total cost from an additional unit of effort, whereas AEC is total cost divided by the total amount of effort applied to resource harvest. For example, constant MEC and AEC means that the cost of operating an oil well or a fishing boat for an hour remains constant.

The economic benefits from effort are measured by revenue generation. As with effort cost, there are two important revenue measures for effort, *marginal revenue product* (MRP) and *average revenue product* (ARP). The MRP is simply the change in total revenue caused by an additional unit of effort; the ARP is total revenue divided by the total amount of effort applied to resource harvest. For example, the revenue generated by operating a fishing vessel for an additional hour is MRP, while ARP is the average amount of revenue generated by an hour of vessel operation. Low levels of total appropriation effort do not harm the productivity of the resource stock, and so ARP and MRP are both high when total effort E is low. For example, if a fishery has not been fished very much, then a vessel can catch a lot of fish in an hour of effort. As total appropriation effort grows, however, the resource stock declines, and so both MRP and ARP decline. The MRP declines more sharply than the ARP because MRP reflects revenue generated by an additional unit of effort on an increasingly depleted resource, whereas ARP reflects the average of revenue from both abundant and depleted resource conditions. Declining MRP pulls ARP down, however, just as a bad set of semester grades will pull down a student's cumulative grade point average.

As shown in Figure 5.4, the efficient level of appropriation effort E^* occurs where $MEC = MRP$. The intuition is similar to the reasoning behind why a profit-maximizing firm in a competitive market will supply a quantity of output where market price equals marginal cost, as discussed in chapter 4. Starting at zero effort, one can incrementally increase effort in one-unit intervals and compare MRP to MEC. As long as $MRP > MEC$, then an additional unit of effort will increase profit. If $MRP = MEC$, then further effort will cause $MRP < MEC$, which will cause profit to decline. The efficient level of appropriation effort leads to maximum Hotelling rent for the group of fishers, which in a more simplified one-diagram model reflects the dynamic efficiency result developed earlier in this chapter. Under conditions of open-access, or when other property rights regimes fail, individual appropriators are unable to work together to limit total effort and maximize Hotelling rent. If one appropriator were to limit effort, the resource units would simply be harvested by someone else. The result is that Hotelling rent is dissipated, which occurs as an outcome of rivalry among individual appropriators. In Figure 5.4, rents are fully dissipated at the level of total effort E^D where $AEC = ARP$, because at this point the average cost of a unit of effort equals the average revenue produced by that effort, yielding zero profit or rent. Note that if you multiply both AEC and ARP by total effort E^D you get $TC = TR$, which means that $TR - TC = 0$.

Figure 5.4 **CPR Appropriation: Full-Rent Dissipation versus Group Optimum**



Gordon's model also indicates that managing a CPR for maximum net social return results in a lower level of effort than what is required to produce the CPR's maximum sustainable yield (MSY). To see this, note that MSY in Gordon's model occurs at a level of total effort where total product appropriated from the CPR is maximized. Therefore, at MSY the marginal product of a unit of effort is zero. Because the market price of the harvested product is assumed to be constant, then MRP at MSY is also zero. Consequently, MSY in Gordon's model occurs at the point in Figure 5.4 where MRP becomes equal to zero by crossing the horizontal axis. Recall that the socially efficient level of appropriation effort occurs where *MEC = MRP*. As MEC is greater than zero, the efficient level of appropriation effort for the appropriators as a group is actually less than what would occur were the CPR managed for MSY. In the case of a fishery, the implication is that the efficient level of effort for the fishers results in a larger stock of fish being maintained in the fishery than what is required for MSY. In contrast, the open-access outcome is not only economically inefficient, but it is also biologically inefficient because it results in a smaller stock of fish being maintained in the fishery than what is needed to achieve MSY.

The dilemma with CPRs is that, unlike the invisible hand of Adam Smith's competitive market, self-interested behavior in a CPR does not yield the efficient outcome. Suppose a village has a common pasture for grazing livestock but lacks effective rules for governing the number of cattle that villagers have grazing on the pasture. In addition, suppose that the pasture is currently being used at its carrying capacity. If a villager adds one more milk cow to the village pasture, the villager gains 100 percent of the benefit of increased milk production, but also creates an appropriation externality of reduced forage and a deteriorating pasture condition shared by all who graze livestock on the pasture. If all villagers act in the same manner, the result will be destruction of the commons. As Hardin (1968) argues:

> The rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another. . . . But this is the conclusion reached by each and every rational herdsman sharing the commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. (p. 1244)

Along the same vein, Gordon (1954) concludes:

> There appears, then, to be some truth in the conservative dictum that everybody's property is nobody's property. Wealth that is free for all is valued by no one because he who is foolhardy enough to wait for its proper time of use will only find that it has been taken by another. (p. 135)

Or for the case of fishery CPRs:

> For years, [Sam] Novello had made a decent living off the abundant groundfish—cod, haddock, yellowtail flounder—that he hauled up off the Atlantic Ocean floor. He used nets with a large-enough mesh size to allow juvenile fish to pass through, and worked the best spots sparingly with his tows. "I didn't know I was a conservationist until somebody told me," he says, "but I believed in only taking the interest out of the bank." But Novello watched many of his competitors make three times as much money depleting vast areas and keeping thousands of pre-spawning-size fish. And he has never forgotten the disdainful words of a local dealer: "What are you, stupid? One boat is gonna save every fish in the sea?" So, he adds sadly, "Finally I said, OK, I'll fish like everybody else does." (Russell 1996)

The process of rent dissipation in CPRs is referred to as the t*ragedy of the commons*, a term coined by Garrett Hardin. The theory behind Hardin's tragedy of the commons is illustrated using a simple strategic model in the appendix at the end of this chapter.

In the past, many economists have argued that the solution to the tragedy of the commons is to assign private property rights. In developing their arguments, these economists have often assumed that an open-access property rights regime is in force, meaning that there are no rules limiting use. Indeed, transforming an open-access resource into a private property resource will attenuate the tragedy of the commons when privatization is desirable and feasible; however, those who study CPRs increasingly argue that appropriately designed common property regimes may also work to prevent this tragedy from occurring. Elinor Ostrom (1990) and her colleagues (Ostrom et al. 1994) have argued that the grim picture of CPR governance failure is not at all universal and that, in fact, there are many examples of long-enduring, sustainable local CPR systems around the world. Additional case study analysis that supports Ostrom's argument is provided by Bromley (1992). Ostrom and her colleagues sought to learn what makes these systems successful and to develop a set of design principles from them that can guide the design of new CPR systems as well as predict CPR success.

Ostrom's central idea is that *localized* CPR systems can be durable and sustainable in situations in which open-access has been replaced by a common property regime established and governed by the local people who depend on the CPR. Sustainable self-governance calls for a set of rule systems or institutions that define the physical boundaries of the CPR, the people who are allowed to use the CPR, the methods and extent of appropriations from the CPR, the methods and financing of monitoring systems, a system for resolving conflicts, and a set of sanctions that are proportionate with the importance of the transgression. An additional characteristic of successful self-governance is that the rule structures must be capable of adapting to changing circumstances, such as those driven by weather cycles or population growth. As Sethi and Somanathan (1996) point out, a key element of the success of local self-governance is the ability of the resource-dependent community to establish codes of conduct and to impose sanctions such as cultural isolation and expulsion from the community upon those who violate these rules of conduct. Local self-governance of CPRs will be addressed again in chapter 15 in the context of sustainable local communities, and those who would like to pursue this issue further may want to jump ahead.

It is interesting to consider factors that might explain why some resources are held as common rather than as private property. Clearly, some resource stocks such as fisheries, groundwater basins, and mobile wildlife are not conducive to being partitioned as private property. Moreover, in his study of common property systems in Swiss alpine villages, Netting (1981) identified five environmental variables that tend to lead to resources being held as common rather than as private property:

- The value of the harvestable resource is low per unit of area.
- The amount of harvestable resource is highly variable.
- Investment in improvements yields a relatively small increase in productivity of the resource.
- Overall costs can be reduced if people can coordinate activities such as herding livestock or processing dairy products.
- Fence, road, and other building costs can be reduced when done on a larger scale.

Evidence shows that this pattern also held for primary societies. McEvoy (1986), for example, observes that highly productive locations for catching salmon along the Klamath River in northwest California were privately owned by individuals or partners in the Yurok tribe before contact with whites. As private property these productive fishing spots could be transferred by way of market-like exchanges, and others were excluded from fishing at or immediately below the spot. Yurok land that was farther from settlements or that was less productive for catching fish had lower economic value and was recognized as a common-property or an open-access resource.

Ostrom and her colleagues (1992; 1994) have also used laboratory experimental techniques to evaluate aspects of CPR theory. Laboratory conditions replicate the key *incentives* of the model under investigation through the use of cash payments to participants, and these cash payments vary based on the appropriation or other decisions that they make. An important element of this research work has been to determine the role of face-to-face communication in creating "social capital" and informal rule systems that can prevent the dissipation of Hotelling rents. Some of the basic results of this research include:

- When participants appropriate from a commons but are unable to cooperate or communicate with one another, the result is that most or all Hotelling rents are dissipated, as predicted by the tragedy of the commons, yielding the rent dissipation outcome in Figure 5.4 (see Ostrom et al. 1992; Ostrom et al. 1994).
- When these participants are allowed to communicate with one another but cannot form enforceable agreements, they usually develop informal rule structures that coordinate reduced appropriation and generate most or all of the potential Hotelling rents shown in Figure 5.4, even though the agreements were not enforceable (see Ostrom et al. 1992; Ostrom et al. 1994).

- When some participants pay to acquire a larger appropriation capacity (e.g., buy a big fishing vessel), the informal rule systems devised through face-to-face communication tend to allocate quotas proportionate with appropriation capacity, which also matches the available evidence from field CPR systems featuring heterogeneity (see Hackett et al. 1994).

Group discussion and communication have been found to be major factors in resolving many social dilemmas such as the tragedy of the commons. Orbell, van de Kragt, and Dawes (1988) found evidence that communication fosters the creation of a group identity, leading to a displacement of egoism for group regardfulness, and allows for consensual promise making, where discussion of the collective benefits of cooperation motivates consensus agreements on limiting resource dissipation by way of promised behavior.

Ecosystem Services and Natural Capital

Imagine trying to set up a fully functional enclosed ecosystem like Biosphere 2 on the moon. What ecosystem services would such an enclosed system need to include? What geological, atmospheric, and biophysical relationships would need to be replicated? Like Noah, we would also need to know what species of plants, animals, fungi, bacteria and other life-forms to include. Unlike Noah we would also need to know how many to bring, which to group together, and what their life requirements are. Daily (1997) includes the following as essential ecosystem services:

- Purification of air and water
- Mitigation of floods and droughts
- Detoxification and decomposition of wastes
- Generation and renewal of soil and soil fertility
- Pollination of crops and natural vegetation
- Control of agricultural pests
- Dispersal of seeds and translocation of nutrients
- Maintenance of biodiversity for uses such as agriculture, medicine, and industry
- Protection from the sun's ultraviolet rays
- Partial stabilization of climate
- Moderation of wind, wave, and temperature extremes
- Support of diverse human cultures
- Provision of aesthetic beauty and intellectual stimulation

Costanza et al. (1997) includes 17 such ecosystem services in their comprehensive study. Clearly, it would be very complex and expensive to replicate these ecosystem services on the moon. As most ecosystem services occur outside of commercial markets, for the most part we take them for granted, and they are assumed not to have economic value. Costanza et al. (1997) observe that "ecosystem goods (such as food) and ecosystem services (such as waste assimilation) represent the benefits human populations derive, directly and indirectly, from ecosystem functions" (p. 253). These ecosystem services represent flows of materials, energy, and information from the stock of *natural capital*. Natural capital consists broadly of the stock of nonrenewable resources, renewable resources, and the elements and relationships embodied in ecosystem functions. Depletion of an element of natural capital, such as when fishery stocks are drawn down, implies that the corresponding flow of harvestable fish also declines. Both constructed and human capital, and more generally all the world's economies, rely upon the functional integrity of natural capital. The economic value of ecosystem services will be touched upon in chapter 6, and the extent to which technology can develop substitutes for natural capital will be addressed in chapter 13.

Resources for the Future: Factors Affecting Future Resource Scarcity

Are we going to be experiencing growing resource scarcity in the future as nonrenewable resources run out, renewable resources are depleted, and the integrity of Earth's ecosystem services is fatally compromised? Or will market price and technology seamlessly guide society to more efficient use of existing resources and develop alternatives for those that are depleted? And what is the role of population?

Thomas Malthus, in his book *An Essay on the Principle of Population* (1798), argued that growth in human population would outstrip the natural resource endowment of the planet. Malthus's arguments were originally focused on the land resource and food production. Malthus believed in the notion of *absolute resource scarcity*, meaning that most important natural resources have no substitutes available now, and technology cannot create substitutes. In Malthus's view, food production could indeed grow; however, this growth would be outstripped by the growth in human population. Because of absolute scarcity, human society will eventually exceed the "carrying capacity" of planet Earth, leading society to collapse. Many ecologists have been heavily influenced by Malthusian thought. "Neo-Malthusians" have generalized the Malthusian argument to include an overall statement about the natural environment, human population growth, and quality of life.

The argument from mainstream natural resources economics is that when adequate property rights have been assigned and enforced, and a resource is allocated through competitive markets, Hotelling's rule indicates that price will reflect the relative scarcity of the resource. Specifically, the more scarce the resource, the larger will be the Hotelling rents, and thus the higher will be the price of the resource. Therefore, market price offers a good indication of overall scarcity. Technological change has allowed us to reduce consumption of increasingly scarce resources by identifying more resource-efficient technologies and by utilizing substitute resources. The energy crisis of the mid- and late 1970s offers another lesson: higher oil prices spurred domestic production of coal and natural gas and created an incentive for research and development (R&D) into alternative energy sources such as solar and wind. Many people were able to reduce their energy use substantially through home insulation and by adapting to lower household temperatures, as well as carpooling and using public transportation. Energy inputs per dollar of produced goods and services have declined substantially in many industrialized countries. A further argument made by many economists is that there is relatively little evidence of growing Hotelling rents in natural resource markets. The inflation-adjusted prices of coal, oil, natural gas, metals such as aluminum, iron, and copper, and basic foodstuffs such as wheat, soybeans, and cattle have not increased, but in many cases have actually declined over the last 30 years, despite the rapid growth in human population.

Economists argue that Malthus assumed *static technologies*, meaning that resource productivity would remain at 1798 levels. Perhaps Malthus took this position because he preceded the rapid technological change that was associated with the Industrial Revolution by several years. In any event, by ignoring the role of technology in increasing resource productivity and facilitating the development of substitutes, Malthus failed to predict that, in fact, from his time to the present, food production actually outgrew human population.

Global resource prices may provide a false indication of resource scarcity, however. As Cohen (1996) points out, prices can provide a false indicator of resource scarcity for at least two reasons. First, prices do not provide information on the scarcity of open-access resources or poorly enforced state and common-property resources being depleted due to tragedy of the commons. Second, resource prices may decline because of production shifts to countries where lack of environmental taxes and regulation leads to a larger proportion of the external costs of resource extraction, use, and disposal not being reflected in price. A third reason one can offer for why prices do not provide a comprehensive indication of resource scarcity is that many important resources and ecosystem services are not and cannot be directly provided for and protected by the individual actions of buyers and sellers in a market. One example is the ecosystem service of atmospheric gas regulation (such as the CO_2 /O_2 balance and O_3 for ultraviolet B protection). Atmospheric gas regulation cannot be easily partitioned and sold as private property in the market. In the absence of government intervention and a coordinated effort, the necessary changes in fuel and land use would not happen. Therefore, market price will not fulfill its role as the signaler of scarcity and depletion, and technology is unlikely to offer us satisfactory substitutes.

Economists such as Anderson and Leal (1991) argue that inadequate resource protection occurs because of an inappropriate property rights regime, and they suggest that the solution is privatization when possible. Yet the stocks of fresh air, marine fisheries, groundwater, stratospheric ozone, biodiversity, and many other resources cannot effectively be partitioned as private property. In addition, it is not clear that resources such as topsoil fertility have been consistently conserved in privately owned farms, or that non-income-generating aspects of the environment such as old-growth-dependent species are adequately protected in privately owned forest lands. Even for those resources for which privatization can effectively reverse degradation, it is not at all clear that such a move would be consistent with community values. For example, in societies with highly unequal distributions of wealth, the privatization solution will put park and open-space access beyond the reach of people with low or modest incomes. Ostrom and others have shown that private property regimes are not necessary for sustainable resource management; common-property regimes can sustain natural resources when they are governed by locally devised and maintained rule structures.

This debate between ecologists and economists over the changing nature of scarcity led to a rather famous bet. In 1980, economist Julian Simon and ecologist Paul Ehrlich made a highly publicized wager on whether the price of a set of metals selected by Ehrlich (copper, chrome, nickel, tin, and tungsten) would rise, remain constant, or fall by 1990. A total of $1,000 worth of these metals was bought in 1980. Ehrlich agreed to pay Simon the difference between the 1980 and 1990 value of this quantity of metals if their aggregate (inflation-adjusted) market price declined, while Simon agreed to pay Ehrlich the difference between the 1980 and 1990 value of these metals if their aggregate (inflation-adjusted) market price rose. In 1990, Ehrlich paid Simon $576.07, indicating that the inflation-adjusted aggregate price of the metals had fallen from $1,000 to $423.93. Ehrlich lost his bet because new sources were found, substitutes were developed for those that had become more scarce, and some metals markets became more competitive. The outcome of this wager would have been different had they bet on factors such as urban sprawl and biodiversity.

Summary

- For something to be a natural resource means that it is an aspect of Earth's endowment that is useful to people in some way. A natural resource has either direct value or value contingent upon the existence of technology that transforms the raw resource into something useful. Thus, petroleum was not a valuable resource until the internal combustion engine, combined with the technology for cracking petroleum into refined products such as gasoline, allowed it to be converted into something useful to people.

- Nonrenewable resources are fixed in total quantity and thus are said to have a fixed stock that does not recharge over the human time frame. Fossil fuels and mineral resources are examples of nonrenewable resources. If steady declines in supply or increases in demand are anticipated in the future, economists have argued that market forces will mitigate against a sudden price shock or "running out" of the resource in question. The reason is that resource owners anticipating higher future prices will have an incentive to sell less today in order to have more to sell at higher future prices. As a consequence, current prices will also rise. Higher current prices in turn cause people to conserve on use of the resource and provide incentive for R&D into technology to make use of alternative resources, such as substituting solar energy for oil, as well as into more resource-efficient technologies. Of course, if unanticipated supply or demand shocks occur, or if there is political manipulation of the process, this rational adjustment may not occur.
- *Dynamic efficiency* occurs in resource markets when the PDV of surplus is maximized. According to Hotelling's rule, this occurs in nonrenewable, nonrecyclable resource markets when the PDV of marginal Hotelling rent ($P - MC$) is equalized over time. If marginal extraction costs remain relatively constant over time, the implication of Hotelling's rule is that the price rises over time. This increase in price will spur conservation and the development of substitutes.
- Recyclable resources such as glass, paper, and metals have a primary market where the original resource is sold and a secondary or recycled market where salvaged resource is resold. Resources in the primary market must thus compete against resources from the secondary market. A monopoly or cartel that controls a natural resource that is recyclable must anticipate future competition from the secondary market when it sets output. Excessive production today will result in excessive competition from the secondary market in the future.
- Renewable resources are aspects of the living planet and can regenerate themselves under sustained-yield management, or become depleted when yield rates exceed the maximum that is sustainable. Natural resource systems are usually a complex of interdependent elements, and the maximum sustained yield of one element may result in overharvest in

the impact on another related resource. An example is overharvest of timber in its effects on watershed and fisheries resources.

- Fisheries are an important case study of a general failure to manage a renewable resource for sustained yield. A central problem with fisheries is that many are open-access in nature, and thus there is no practical way to limit harvest levels. Worldwide, the total number of fishing vessels doubled from 1970 to 1990, yet the total catch in 1990 could easily have been made with the 1970 stock of vessels, implying that there is substantial overcapitalization. Countries are working at reducing the numbers of fishing boats and other elements of effort, including individual marketable quotas.
- Common-pool resources (CPRs) are resources for which it is difficult to prevent multiple individuals from harvesting resource units, and resource units harvested by one are not available for another. Thus, CPRs differ from private goods, where it is possible to exclude others from use, and pure public goods like public radio, where my use does not impair your use. Garrett Hardin coined the term *tragedy of the commons* to refer to the common situation in which individuals overuse the commons because of the presence of appropriation externalities: if you graze more cattle, you get the financial gain, while the damage to the common pasture is borne by everyone in the community. Elinor Ostrom has argued that the tragedy of the commons can be (and has been) avoided through the construction and maintenance of carefully crafted CPR governance structures.
- Ecosystem services, such as the supply of fresh water, soil fertility, and climate regulation are the benefits that human society receives, both directly and indirectly, from ecosystem functions. Costanza and colleagues observed that these ecosystem services represent flows of materials, energy, and information from the stock of *natural capital*.
- The argument has raged over whether or not there is growing resource scarcity as a consequence of growing population, as Malthus originally argued. In fact, the price of many marketed natural resources such as coal, oil, natural gas, forest products, seafood, and pasturage has not risen as rapidly as some predicted and in many cases has actually fallen. This has reinforced the arguments of the technological optimists such as Julian Simon. Conversely, in many parts of the world, ecosystem services as well as common-property and open-access resources are being depleted. There is truth in both camps: human ingenuity indeed has offset substantial amounts of resource limitations with technological advances, but other unique and irreplaceable resources are under increasing pressure, and many are failing.

Review Questions and Problems

1. Suppose that in the oil example given in the chapter for dynamic efficiency, all else remains the same except that the discount rate *r* rises from 15 percent to 30 percent. Using the technique shown in the chapter, determine how this increase in the discount rate will change the dynamically efficient allocation of oil across the two periods, and how it will change the size of the marginal Hotelling rent on each barrel of oil.

2. Suppose that in the oil example given in the chapter for dynamic efficiency, all else remains the same except that now there are 60 barrels of oil rather than only 40. Using the technique discussed in the chapter, determine how this increase in the availability of oil affects the dynamically efficient allocation of oil across the two periods, and how it will change the size of the marginal Hotelling rent on each barrel of oil.

3. Carefully define a common-pool natural resource relative to both private goods and pure public goods. Provide an example. Use this example to explain the tragedy of the commons. If resource users can govern themselves, what sort of rules might prevent the commons from becoming damaged from overuse?

4. Explain why the pure Malthusian outcome has not occurred, despite rapid population growth since Malthus's time (1798). Carefully list the factors that would explain why some resources have not grown increasingly scarce and why some have substantially degraded. The role of technology and the possibility of substitution should be at the center of your explanation.

5. Suppose there is a groundwater basin that is being drawn from faster than it is being recharged from its aquifer, resulting in dropping water tables in the area. Explain the different ways that people can improve this situation.

Internet Links

California's Independent Electricity System Operator (http://www.caiso.com/): Learn about partial deregulation of California's electric energy industry.

Economic Sustainability and Scarcity of Natural Resources (http://www.rff.org/issue_briefs/PDF_files/tahvonen_naturalres.pdf): Olli Tahvonen of the Finnish Forest Research Institute in Helsinki traces the history of economic thinking about scarcity of natural resources and the sustainability of economic growth. A June 2000 Resources for the Future *Issue Brief*.

Food and Agriculture Organization (http://www.fao.org/): The United Nations Food and Agriculture Organization (FAO) is an excellent source of information on important agricultural and natural resources, including fisheries and forests. The FAOSTAT datebase (http://apps.fao.org/) is particularly valuable.

Food and Agriculture Organization's Fisheries Department (http://www.fao.org/fi/default.asp): The place to access various reports on the state of the world's marine fisheries, inland fisheries, and aquaculture.

Food and Agriculture Organization's Forestry Department (http://www.fao.org/waicent/FAOINFO/Forestry/Forestry.htm): A good overview of global forestry issues.

Forest and Rangeland Ecosystem Science Center (http://fresc.fsl.orst.edu/): Learn more about forests and rangeland resources.

Hotelling's Rule Audio Clip (http://www.humboldt.edu/~envecon/audio/2.ram): A brief audio clip of the author describing Hotelling's rule.

Interactive Hotelling's Rule Simulation (ftp://www.sorrel.humboldt.edu/pub/envecon/module3.xls): An Excel-based interactive simulation provided on the Internet site for this book. It can be used to demonstrate the dynamic efficiency of Hotelling's rule. Click "yes" to enable macros. You do not need to know how to use Excel to use this simulation as it is entirely menu-driven.

International Association for the Study of Common Property (http://www.indiana.edu/~iascp/): A good place to learn more about systems of governance for common-pool resources.

Malthus Website (http://socserv2.socsci.mcmaster.ca/~econ/ugcm/3ll3/malthus/index.html): Read Malthus's original work on population.

National Marine Fisheries Service (http://www.nmfs.gov/): Learn about federal regulation of U.S. marine capture fisheries.

***Rangeland* (http://uvalde.tamu.edu/rangel/home.htm)**: A publication of the Society for Range Management.

World Resources Institute (http://www.wri.org/): Excellent source of global information on the state of the world's natural resources.

World Resources Institute's Sustainable Agriculture Site (http://www.wri.org/wri/sustag/): Learn more about sustainable agriculture.

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Appendix: The Theory Underlying the Tragedy of the Commons

The "tragedy of the commons" is most likely to occur under the conditions of open-access or other poorly designed and enforced property rights regimes. The tragedy of the commons outcome results from strategic behavior—behavior that an individual takes based on how other people are expected to behave or respond. At the heart of the tragedy of the commons is the belief that if one were to conserve the CPR, others will take what was conserved, and the CPR will still degrade. Mathematicians refer to situations like this, in which people are taking strategic actions based on how other people are expected to behave or respond, as *games*, and the theory used to analyze the outcomes of such situations is referred to as *game theory*.

The tragedy of the commons can be described by a more general game called "prisoner's dilemma." In the prisoner's dilemma there are two prisoners, Chang and Adams, who are being investigated in regard to a crime punishable with a fine. Unless one or both of them confess, there is insufficient evidence to convict them, and they will go free and pay no fine. If one of the prisoners were to confess and provide evidence to implicate the other, while the other claims innocence, then the prisoner who confesses will receive a $500 cash reward, while the prisoner claiming innocence will be convicted of a crime and have to pay a $5,000 fine for lying and claiming innocence. If both confess, then they both will be convicted of a crime, but because they confessed, each will only have to pay a $1,000 fine. The prisoners are separated and do not know how the other will respond to this situation and are unable to coordinate their actions. Assume that the implicated prisoner cannot later punish the other prisoner for providing evidence.

The *payoff structure* that forms the incentives for this game is summarized in Table 5.3.

In this situation, each prisoner is confronted with the choice of "confess" or "claim innocence" and with a conjecture of what the other prisoner will

Table 5.3

Strategic Form of the Prisoner's Dilemma Game

	Chang claims innocence		Chang confesses	
Adams claims innocence	A: $0	C: $0	A: –$5,000	C: $500
Adams confesses	A: $500	C: –$5,000	A: –$1,000	C: –$1,000

Note: "A" denotes Adams's payoff, while "C" denotes Chang's payoff.

do. To determine the Nash equilibrium to this game (named after John Nash, a game theorist), first consider Chang. Chang knows that if Adams confesses, then Chang will be fined $5,000 if he claims innocence, or fined $1,000 if he also confesses. In this circumstance, Chang is best off to confess. If instead Adams claims innocence, then Chang will receive a $500 cash reward for confessing, or get off free and pay $0 fine if he also keeps quiet. In this circumstance, Chang is also best off to confess. Thus, Chang has what is known as a *dominant strategy* of confessing. This strategy is referred to as being dominant because Chang will confess regardless of what Adams does.

Now consider Adams, whose situation is exactly the same as that of Chang. If Adams believes Chang will confess, then Adams will be fined $5,000 if he claims innocence, or fined $1,000 if he also confesses. In this circumstance, Adams is best off to confess. If instead Adams believes that Chang will claim innocence, then Adams will receive a $500 cash reward for confessing, or get off free and pay $0 fine for also claiming innocence. In this circumstance Adams is also best off to confess. Thus, Adams also has a dominant strategy of always confessing regardless of what Chang does.

The Nash equilibrium outcome of the prisoner's dilemma is (confess, confess), and both parties are fined $1,000. Note that this outcome is inefficient relative to the (claim innocence, claim innocence) outcome, in which both parties pay no fine, but that outcome is not an equilibrium because both parties have an incentive to defect and confess if they believe the other will claim innocence.

You may already see that the strategic structure of the prisoner's dilemma game is also that of the CPR dilemma. If we rename this game CPR dilemma, the strategy of "claiming innocence" is renamed "sustainable use," and the strategy of "confessing" is renamed "resource depletion." Thus, the equilibrium of the CPR dilemma game is (resource depletion, resource depletion), which is inferior to that of (sustainable use, sustainable use). If Adams believes that Chang will use the resource sustainably, Adams's dominant strategy is to capture the resources left by the other and deplete the resource. Chang has the same dominant strategy, which yields the tragedy of the commons outcome of the CPR dilemma game.

Of course, in the context of a CPR dilemma, the payoffs from (sustainable use, sustainable use) will be positive rather than the $0 payoff used in the prisoner's dilemma game for (claim innocence, claim innocence). Nevertheless, the same result will occur with positive payoff values in the upper left cell of the bimatrix table, as long as the payoff to confessing given that the other is claiming innocence is larger than the payoff when both claim innocence.

Possible methods of avoiding the tragedy of the commons outcome include (1) changing the payoff structure of the game, (2) repeated play, and (3) cooperative rather than noncooperative decision making. The payoff structure of the game can be changed, for example, if there is a CPR governance structure that imposes substantial sanctions on those who violate the sustainable use rules and deplete the resource (akin to prisoners' being able to credibly threaten to punish those who "rat" and implicate others through confession). Under repeated play, it may be possible for the value of future sustainable use to weigh against depleting the resource today, though this may require an effectively infinite horizon of repeated play. If the noncooperative nature of the game is transformed into a cooperative game through some form of CPR governance structure, then the jointly optimal outcome can be realized through coordination.

Part II

Policy

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6

Measurement and Analysis of Benefits and Costs

Introduction: Benefit/Cost Analysis

This chapter provides an overview of the methods used to measure the benefits and the costs of environmental protection, as well as a description of benefit/cost analysis (BCA). Enhancing environmental conservation and restoration entails opportunity costs. Examples of these opportunity costs include the economic value of harvested timber, fishery, or mineral resources left undeveloped; the profitable investment opportunities lost when firms are required to invest in pollution-control machinery and equipment; and the alternative use of tax revenues allocated by government for increased monitoring and enforcement. Though there are many philosophical and conceptual problems with benefit/cost analysis (which we will explore below), policy decisions are made in the context of scarcity, and so policy decisions entail opportunity costs. Informed decision making ultimately requires that we rank alternatives and confront the net benefits of one policy option with the opportunity cost of that choice. Unless society can agree that certain environmental policies are intrinsically right, it is very difficult to avoid some form of BCA of social policy.

Although costs are frequently measured in monetary terms, many of the benefits of environmental policy derive from improvements in aspects of the environment and human health that are not traded in markets, and so their value is not expressed in monetary terms. Thus, a common metric is needed to compare the "apples and oranges" of benefits and costs. People routinely make the "apples and oranges" comparison of benefits and costs for themselves based on their values and preferences. Whenever people buy a good or service, they are comparing money cost with the utility or pleasure of the good that they anticipate receiving in exchange. If people know the quality of the good before purchase, then we can use the money that they spend on a good or service as a measurable indicator of their unmeasurable utility. If we aggregate the money spent on a particular good or service by all buyers, we can get a measure of the aggregate or social utility generated by that good or service. But what if we are trying to measure the social utility of protecting an aspect of the natural environment that is not bought or sold in markets? We will discuss various techniques for measuring the value of nonmarketed environmental amenities later in this chapter.

Another metric for aggregating utility is provided by political systems. In democratic systems we can use voting patterns as a binary indicator of the relative utility that voters have for various political candidates or ballot measures. Of course, because all human societies feature inequalities of wealth and power, both markets and politics are flawed instruments for measuring social utility. Benefit/cost analysis usually uses money as a measure of utility, and thus monetizing benefits and costs is an important aspect of such an analysis. In chapter 7 we shall discuss political economy, which evaluates policy alternatives based on preferences revealed through voting and political influence.

One of the earliest discussions of BCA was offered by Dupuit (1844). Dupuit argued that the output of a project (e.g., water generated by a water filtration system) multiplied by per-unit market price gives an estimate of the minimum social benefit of the project. Some consumers are willing to pay more, but this information may not be available for valuation purposes.

One of the first applications of BCA was in the U.S. Flood Control Act of 1936. In this legislation, Congress declared that the benefits associated with federal projects, “to whomsoever they may accrue,” should exceed costs. While benefits were supposed to exceed costs, no consistent methods were offered for measuring these benefits and costs. The Corps of Engineers, Soil Conservation Service, Bureau of Reclamation, and so on, all used different approaches. In 1950, the Federal Interagency River Basin Committee issued a publication titled *Proposed Practices for Economic Analysis of River Basin Projects*, also known as the “green book,” which provided a uniform best-practices guide for various agencies involved with public projects.

In the current environmental policy debate, BCA has become a highly charged, controversial issue. Some wish to increase the use of BCA in order to enhance the efficiency of government regulation. It can be argued, however, that BCA is inappropriate as the single deciding policy factor in many circumstances where its use is proposed. Elements of this argument include:

- Using BCA as the single deciding factor in setting policy assumes implicitly that the values of all objects and states of affairs are commensurable, meaning that they can be ranked based on a single characteristic of value such as money or utility. Yet issues of fairness, ethics, and spirituality may not be commensurable with monetized costs or benefits. Can we compare the value of a unique sacred place to the revenues and jobs created by logging, mining, or grazing that same site?

- Scientists and others do not fully understand the interdependencies in ecosystems, so when we do BCA on one element of the ecosystem (for example, on preserving a particular species or damming a segment of river), we cannot understand the benefit/cost implications for all the other elements of the ecosystem. In other words, social and ecological systems may be too complex to quantify comprehensively through BCA.
- Some of the benefits of environmental improvements include the reduced loss of human life. Placing an infinite value on a human life in BCA would lead to the conclusion that all the world's resources should be allocated toward prevention of any one death, an unlikely choice of social policy. Yet if we measure the value of a human life based on income generation, then the analysis will tell us that a life in a rich country is worth more than one in a poor country. In this case, BCA will yield the unethical conclusion that it is "efficient" to dispose of toxics and other life-threatening pollutants in low-income countries because lives saved in rich countries are worth more than lives lost in poor countries. For example, Bowland and Beghin (1998) estimated that the value of a statistical life saved in Santiago, Chile, due to reduced air pollution is approximately $600,000, which is only about 12.5 percent of the $4.8 million value of an American statistical life used by the EPA (USEPA 1997). The Nazis applied similar "efficiency" arguments regarding the differential value of human lives to justify the euthanasia of groups such as the disabled. Thus, BCA can lead to environmental discrimination and racism.
- When we use BCA to evaluate projects or policies that affect future generations, we must somehow decide on how to bring the benefits and costs accruing to these future generations into the present. While discounting clearly makes sense in individual behavior, if we apply discounting to BCA, are we robbing future generations to benefit the present? Moreover, because we do not know the values and preferences of future generations we must project our own upon them.
- When we monetize benefits and costs without regard to who receives them, we are implicitly assuming that a dollar generates the same incremental gain in pleasure or marginal utility to all people. Yet this is not generally true when wealth is rather unequally distributed; in such cases, a $10 gain to a mother with a hungry child likely generates substan-

> tially higher marginal utility than it would to a billionaire. Hence, policies that generate the greatest net monetary benefit may in fact generate a substantially inefficient level of human happiness when we assume that the marginal utility of money is the same for all people.

While it is clear that monetization and BCA capture at best only parts of the total impact of a policy, and should not be considered a sole guide to policy, data on benefits and costs can be informative and valuable. Along these lines Munda (1996) and others argue for *integrated environmental assessment*, which combines BCA with other ecological, social, and political factors in environmental policy analysis.

Efficiency

An economic process is said to be efficient if it produces something of value with a minimum of waste. What we mean by waste, however, depends on our norms and objectives. For example, if the objective is to maximize profit, then a timber company will want to use least-cost harvest methods to prevent the waste of potential profit. Doing so, however, may result in damage to the ecosystem of the affected area. Yet, since the objective is to maximize profit, damage to the ecosystem is not counted as waste; in this context, waste would be defined as lost profits created by more costly sustainable forestry practices.

Conversely, if the objective was sustainable forestry, then a clear-cut would create waste because it would damage aspects of the ecosystem that are integral to sustainable forestry practices. In the specific context of BCA, efficiency refers to the extent to which a particular policy improves upon status quo social utility as measured by net (monetary) benefits. If there is a range of possible policy options, then the efficient policy option is the one that generates the largest improvement in social utility. As was discussed in chapter 2, there are two different criteria for judging the efficiency of social policy. The *Kaldor–Hicks efficiency criterion* states that the efficient policy option generates the largest net monetary benefits relative to the other policy alternatives. In contrast, the more restrictive *Pareto efficiency criterion* states that an efficient policy option makes some people better off and no one worse off when compared to the status quo. The Pareto criterion is considered to be nearly impossible to satisfy in actual policy analysis, and so Kaldor–Hicks is the usual efficiency criterion used. While the usual method of performing BCA is to maximize the present discounted value (PDV) of net monetary benefits (as described below), an alternative method is to select policies that generate the greatest amount of monetary benefit for each dollar of cost, called the *benefit/cost ratio*. The ratio method tends to favor smaller projects, whereas the net monetary benefit method tends to favor larger projects. In the presentation that follows, we will assume that the Kaldor–Hicks efficiency criterion is applied to the PDV of net benefits.

Maximizing Net Present Discounted Value (PDV): Dynamic Efficiency Revisited

The concepts of PDV and dynamic efficiency were first introduced in chapter 5. Here we will apply the PDV methodology to benefit/cost analysis. To calculate the PDV of net benefits, we must first estimate the flow of benefits and costs from various project alternatives for each year into the future. Then we choose an appropriate discount rate (the rate of interest charged if you lend money for a year rather than use that money yourself) and compute the PDV of the net benefits for each year into the future. As we learned in chapter 5, we can calculate the PDV of net benefits as follows:

$$PDV = (B_0 - C_0)/(1 + r)^0 + (B_1 - C_1)/(1 + r)^1 + \ldots + (B_n - C_n)/(1 + r)^n.$$

Note that C = cost in a given time period, B = benefit in a given time period, r = discount rate, and n = the end period of the project in years from the present. For example, $(B_1 - C_1)$, refers to net benefits received one year from the present. The expression $(1 + r)^n$ means that the sum $(1 + r)$ is taken to the nth power. Note that discounting will tend to undermine those policies that have large up-front costs, and benefits that are cast into the future, such as with greenhouse gas emissions control and global warming. To see this, note that the PDV of $100 of benefit received 50 years from now, using a standard 10 percent discount rate, is only 85 cents. Therefore, 85 cents deposited today in a financial investment paying 10 percent interest will compound in value to $100 in 50 years. If the federal government routinely uses a 10 percent discount rate, then spending more than 85 cents on a policy today that will generate $100 of benefits 50 years from now will not pass a benefit/cost test. This subject will be discussed in more detail in chapter 12.

An Illustrative Example of Benefit/Cost Analysis

Acid rain in the eastern United States and Canada is caused by sulfur dioxide emitted primarily by coal-burning, electricity-generating plants in the American Midwest. We can consider a variety of different levels of sulfur dioxide control. Benefit/cost analysis can be used to determine the policy alternative

Table 6.1

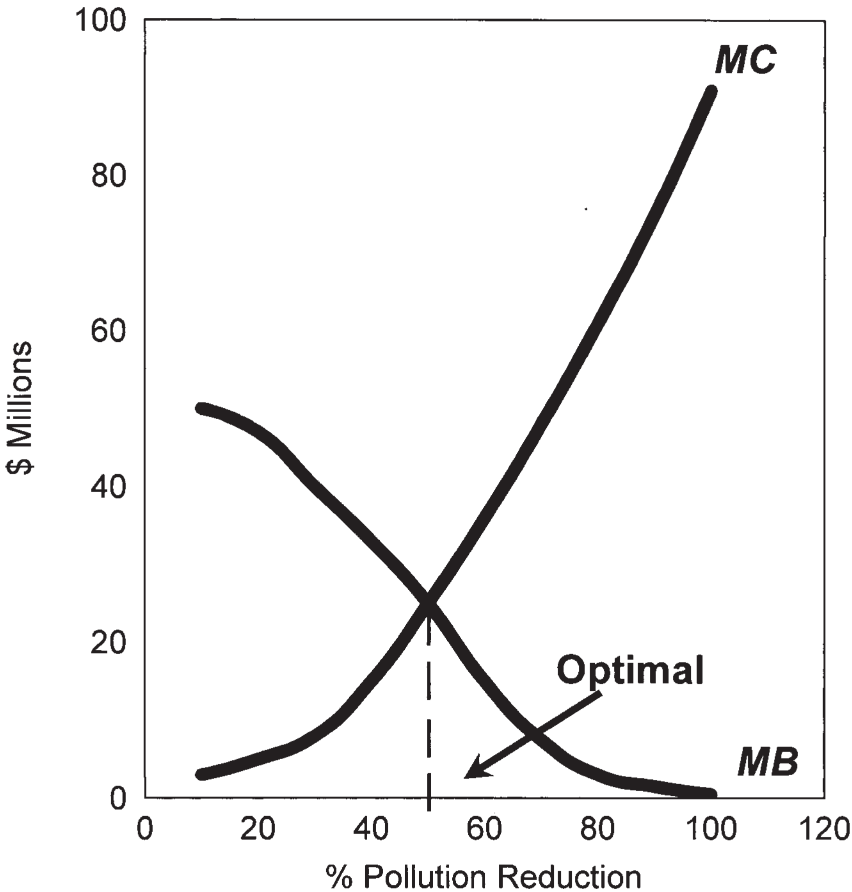
Hypothetical PDV of Costs and Benefits for Control of Sulfur Dioxide Emissions (in millions of dollars)

1. Percentage of sulfur dioxide emissions eliminated	2. Total cost	3. Marginal cost (change in 2 divided by change in 1)	4. Total benefit	5. Marginal benefit (change in 4 divided by change in 1)	6. Marginal net benefit (5 minus 3)	7. Total net benefit (4 minus 2)
10	30	3	500	50	47	470
20	80	5	970	47	42	890
30	160	8	1,370	40	32	1,210
40	310	15	1,700	33	18	1,390
50	560	25	1,950	25	0	1,390
60	920	36	2,100	15	–21	1,180
70	1,400	48	2,175	7.5	–40.5	775
80	2,010	61	2,205	3	–58	195
90	2,760	75	2,220	1.5	–73.5	–540
100	3,670	91	2,225	.5	–90.5	–1,445

that yields the largest net monetary benefit. Consider the hypothetical PDV of costs and benefits (in millions of dollars) associated with each incremental 10 percent reduction in sulfur dioxide in Table 6.1. Assume for a moment that the monetary values given in Table 6.1 fully measure the benefits and the costs associated with controlling sulfur dioxide emissions.

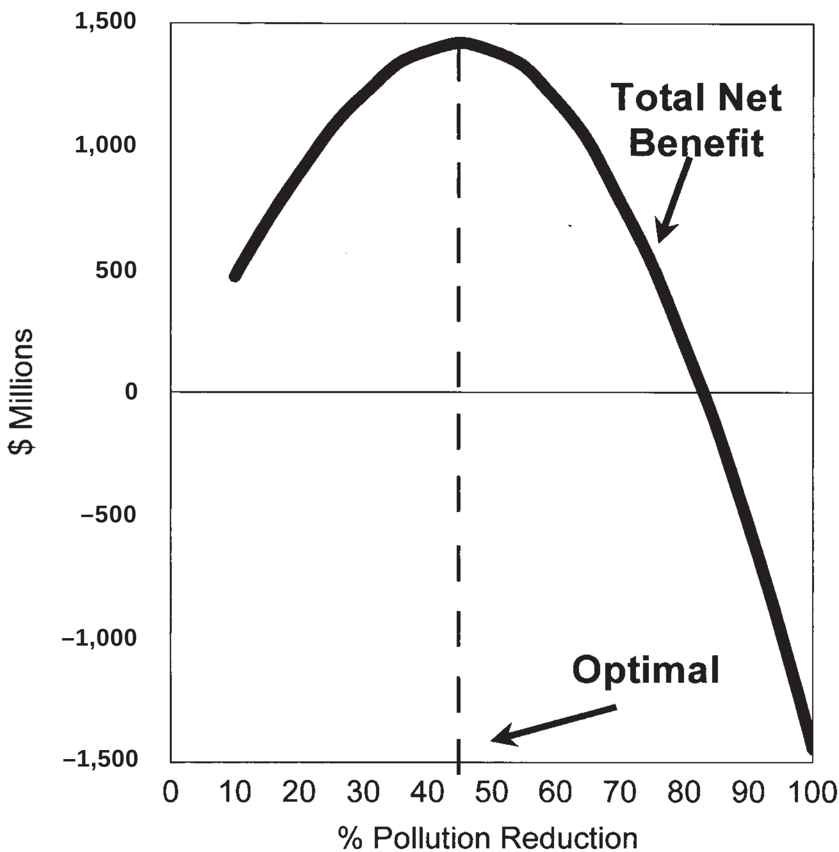
Figures 6.1 and 6.2 plot some of the key data in Table 6.1 and reveal an important relationship between marginal net benefit and total net benefit. When an additional increment of pollution abatement generates marginal benefits (MB) that exceed marginal cost (MC), then marginal net benefit is positive, and therefore total net benefit increases with additional cleanup. At some point, an increment of additional pollution abatement will generate an MB that is equal to MC, which means that marginal net benefit is zero, and total net benefit remains unchanged. Any further increment of additional pollution abatement will generate MB that is less than MC, which means that marginal net benefit is negative, and total net benefit declines. Therefore, total net benefit is maximized when marginal benefit equals MC. This illustrates a more general analytical tool used in microeconomics, called *marginal analysis*, which helps us identify a maximum (such as the maximum total net benefit in Table 6.1) by evaluating MB and MC. The equimarginal principle states that the optimal allocation occurs when MB equals MC. Recall that we used marginal analysis in chapter 4 to find the competitive market supply curve using the “price equals marginal cost” rule.

Figure 6.1 **Efficient Level of Pollution Control Occurs Where *MB* = *MC***



The efficient level of sulfur dioxide pollution control is found where total net benefits are maximized, which in the example above happens to occur at the 50 percent level of control. To see how we arrive at the conclusion that the 50 percent level of pollution control maximizes total net benefits, apply the methodology described in the preceding paragraph. Note that as one begins the first increment of the cleanup process, marginal net benefits are positive, meaning that the initial 10 percent increment of cleanup adds marginal benefits that exceed marginal cost. Therefore, the first 10 percent increment of cleanup causes total net benefits to increase. Likewise, as long as

Figure 6.2 **Total Net Benefit Curve**



an additional increment of cleanup generates positive marginal net benefits they will continue to increase total net benefits. At some point marginal net benefits will become zero, which corresponds to maximum total net benefits. When marginal net benefits of further cleanup become negative, which occurs when the level of cleanup increases from 50 to 60 percent in the example above, total net benefits decline with further cleanup. Consequently, in our example the efficient level of sulfur dioxide pollution control occurs at the 50 percent level of control.

Note that in our example the marginal costs of cleanup are rising, while the marginal benefits are falling. While this does not always have to be the case, we generally expect marginal costs to rise. For example, the first 10 percent reduction in sulfur dioxide may be accomplished by rather inexpensive replacement of low-sulfur for high-sulfur coal in coal-burning electric generator facilities; yet the last 10 percent reduction in sulfur dioxide (from 90 percent control to complete elimination of all sulfur dioxide emissions) may require the immediate elimination of all fossil fuel burning in the world, which would entail an enormous short-term cost. We may expect the marginal benefits of sulfur dioxide control to decline; the first 10 percent reduction occurs in a highly polluted situation, while the last 10 percent reduction may have little noticeable effect because the environment can naturally assimilate that last 10 percent of emissions.

It has been pointed out that we may not need regulations to achieve the efficient level of pollution control described above. In particular, economist Ronald Coase argued that the efficient outcome may also be realized if we assign and enforce property rights and allow people to resolve pollution disputes through negotiation. We will consider this point in greater detail below.

The Coase Theorem

The Coase theorem is based on a very simple and intuitive argument. Suppose that environmental protection or enhancement benefits one group of people and imposes costs on another. If the benefits of environmental protection exceed the cost, then the positive total net benefits from cleanup can be thought of as a pie to be divided among members of society. The size of the pie is maximized at the efficient level of pollution control, such as the 50 percent level of control in the example in the preceding section. Suppose that all stakeholders involved with a localized pollution problem are cognizant of the efficient level of pollution control. The Coase theorem simply states that a way to achieve this efficient outcome would be to (i) determine who holds the relevant property rights and (ii) arrange for a payment that makes it mutually satisfactory for all parties to adopt the efficient pollution-control outcome. For example, suppose there is an auto body shop near a new housing development in the process of being built. The city's nuisance law has a threshold of 125 decibels, and the body shop emits 120. In this case, the body shop holds the relevant property rights. Suppose that there are two ways to eliminate the noise. One is to move the body shop at a cost of $300,000, and the other is to install sound-absorbing materials in the shop for $100,000 that will eliminate the bothersome noise. Also suppose that eliminating the noise will result in a $1 million increase in residential property values in the development. In this case, the installation of sound-absorbing materials is efficient, generating a $900,000 pie. With the rights held by the body shop, the Coase theorem simply states that the efficient outcome can be realized by having the developer enter into a legally binding contract with the auto body shop in which the developer pays to install the sound-absorbing material. Now suppose instead that the city's zoning law gives the residents a property right to a sound-free living environment. As before, the efficient solution is to install sound-absorbing materials in the body shop. With the rights held by the developer, the Coase theorem states that the efficient outcome can be realized by having the body shop enter into a legally binding contract with the developer in which the shop pays to install the sound-absorbing material. Either way, the efficient outcome is achieved without government regulatory intervention.

What Coase and other economists found interesting is that the same overall social efficiency gain will result regardless of who "owns" the right to control the environmental improvement. The Coase theorem, which states that private negotiation can yield the efficient outcome without government regulatory intervention, will hold under the following conditions:

- It is feasible and appropriate to assign property rights to aspects of the environment such as clean air and water.
- There are positive net benefits from environmental improvement.
- The *transaction costs* of coordinating people and conducting the negotiation process are low.
- There is no *free rider problem* in gathering payment funds from a group of stakeholders.
- Any agreement that is reached is legally enforceable.

In addition to the problems mentioned at the start of the chapter in regard to monetization and BCA, Coasian contracting is also plagued by transaction costs and free-riding. *Transaction costs* are simply the costs associated with arranging a transaction. In the case of Coasian contracting, the cost of bringing together and coordinating large numbers of stakeholders would require large expenditures for coordination and communication. *Free-riding* refers to behavior in which people receive benefits from the creation of a public good or a common-pool resource, but choose not to make a voluntary contribution toward the production of those goods. Transaction costs and free riding tend to become larger as more and more people are included in the negotiation process. For example, suppose that we tried to use Coasian contracting to resolve the problem of halocarbons damaging Earth's stratospheric ozone layer. Billions of people benefit and would either need to be compensated or to make a payment, depending upon who holds the relevant rights. The cost of coordinating such negotiations would entail prohibitive transaction costs. In addition, with large numbers of people benefiting from a cleaner environment trying to pool money to buy out a major polluter, a self-interested individual might say, “The plan will work even if I don’t pay my $50,” with the result (possibly) being a failure of collective action. For these reasons, Coasian contracting is far more likely to be used for small-scale environmental problems involving small numbers of affected individuals. When large numbers of people are involved, government intervention can reduce both transaction costs and the free-rider problem that would otherwise exist under Coasian contracting.

Operationalizing Benefit/Cost Analysis in U.S. Environmental Policy

Ever since Executive Order 12044, issued by President Jimmy Carter in 1978, federal regulations such as those for protecting health, safety, and the environment are required to be cost-effective, and federal agencies must quantify the benefits and costs for the various regulations that they administer. As Viscusi (1996) points out, this cost-effectiveness test did not tend to screen out inefficient methods of regulatory administration because alternative regulatory methods were rarely identified. Ever since Executive Order 12291, issued by President Ronald Reagan in 1981, the federal government must show that regulations pass a benefit/cost test. In an important U.S. Supreme Court case dealing with an Occupational Safety and Health Administration (OSHA) cotton-dust regulation in the workplace, however, the Court argued that the legislative mandate placed a feasibility test rather than a benefit/cost test on such regulation (*American Textile Manufacturers’ Institute v. Donovan*, 452 U.S. 490 [1981]). In *UAW v. OSHA*, 938 F.2d 1310 (DC Circuit, 1991), the U.S. Court of Appeals allowed that OSHA was not foreclosed from using a benefit/cost test in the promulgation of its regulations. Viscusi (1996) reports that many federal regulatory agencies currently interpret their mandate as exempting them from the executive orders regarding benefit/cost testing. In Executive Order 12866, the Clinton administration broadened the definition of benefits in Reagan’s executive order to acknowledge the difficulty of monetizing all relevant regulatory benefits.

The Safe Drinking Water Act (SDWA), reauthorized in 1996, now requires the Environmental Protection Agency (EPA) to utilize BCA for new regulations. Though the SDWA requires the EPA to publish these benefit/cost analyses, it does not bind the EPA to reject regulations based on their failure to pass a benefit/cost test. The Clean Air Act (CAA) amendments of 1990 required the EPA to conduct a BCA of the original CAA of 1970. In their report, the EPA (USEPA 1997) stated that the benefits of the CAA between 1970 and 1990 had a central estimate of $22.2 trillion in constant 1990 dollars. Only a subset of the known negative externalities associated with air pollution was included, primarily adverse human health effects, along with some agricultural and visibility impacts. Because of resource and data limitations, improvements in ecological and other conditions were not quantified in the assessment. For this reason the estimated benefits can be considered understated. Estimates of the direct costs of complying with the CAA during this period are approximately $500 billion in constant 1990 dollars. Thus, each $1 of compliance cost to the economy is estimated to have generated over $44 in benefits. It is interesting to point out that the original CAA was widely seen as being more costly than necessary. The CAA amendments of 1990 included an experiment in incentive regulation (to be discussed in chapter 9) as a means of reducing these compliance costs.

Now that we understand the concepts and the practices of BCA, we will turn to a discussion of the methods for measuring benefits and costs.

Measuring Benefits

Overview

People derive many benefits from ecosystems and natural resources, ranging from recreation to wildlife habitat, and from food and raw materials production to nutrient cycling and soil formation. For instance, swamps and other wetlands used to be considered of little value and were frequently drained for agricultural uses. More recently, ecologists have identified many vital ecosystem functions performed by these areas, and economists have developed tools for estimating the monetary value of these functions. In a comprehensive study attempting to estimate the value of various ecosystem and natural resource services, for example, Costanza et al. (1997) report that the nutrient-cycling function of estuaries generates annual benefits worth $11,100 to $30,100 per hectare, while the water-supply function of swamps and floodplains yields annual benefits worth $7,600 per hectare. This section of the chapter provides an overview of the various techniques that economists have applied to measuring the benefits of environmental and natural resources.

To introduce the economic problem of measuring benefits, consider the example of particulate emissions. Particulate matter will cause some harms to commercially valuable goods and services. These damages will be manifested in changes in market conditions that can be gauged using standard supply-and-demand analysis. For example, as we will consider in greater detail in the next section of the chapter, risk-assessment methods can be used to measure the harms to human health caused by breathing a certain quantity of particulate matter. Premature death and illnesses lead to lost earnings that can be quantified when assessing the benefits of reducing particulate matter.

Particulate matter also damages exterior paint, and one can estimate the extent of these damages that will be created by a certain level of cleanup. Reduced particulate emissions in a particular area will likely increase real estate values in a predictable way, as people will find the area more desirable to live in. Moreover, when visual aesthetics are an important part of a local economy, such as with tourism in the Grand Canyon area, then reduced ambient concentrations of particulate matter will generate measurable increases in tourism-based income. There may also be measurable improvements in crop yields. More generally, environmental cleanup will generate some benefits to things whose value is revealed in markets.

As we have seen in the discussion above and in previous chapters, well-functioning competitive markets are useful because they reveal value. For goods and services that are marketed, we can derive consumer surplus from market demand and thereby estimate the net value of the good or service to consumers. But pollution such as particulate matter also impacts on people and ecosystems in ways that cannot be deduced directly from market impacts. The measurement process is more difficult when trying to determine the benefits provided by conserving or restoring nonmarketed aspects of the environment because there is no market price or wage to indicate value. Thus, economists have developed methods of nonmarket valuation to estimate the demand for environmental conservation and restoration. Before we address the various methods of demand estimation for nonmarketed environmental qualities, however, we must first consider how to deal with situations in which environmental improvements result in reductions in health and safety risks.

A particular challenge associated with policies such as toxic emissions control is that many of the benefits to society are in the form of reduced *probabilities* or *risks* that an individual member of society will suffer measurable harm, such as contracting cancer or some illness associated with the pollution emissions. Hence, quantitative risk assessment is an important element of measuring benefits.

Measuring the Health and Ecological Benefits of Regulation: Quantitative Risk Assessment (QRA) and the Value of a Statistical Life

Many environmentally damaging practices such as pollution generate harms to human health that are recognizable in overall populations, but which have uncertain effects on any single individual. A natural example is the emission of toxic pollution into air or water, which elevates the risk of a person contracting cancer, emphysema, or various reproductive disorders. In this case, one way to view the harm is the elevated likelihood of a person becoming ill or dying. Thus, a benefit of environmental protection is the reduction in the probability of a person experiencing specific adverse health effects. Health risk assessment provides a basis for quantifying the benefits of different regulatory options. Likewise, ecological risk assessment is used to evaluate the potential adverse effects that human activities have on the plants and animals that make up ecosystems. The EPA's National Center for Environmental Assessment (NCEA) Internet site describes the steps involved in risk assessment:

> Tools for quantitative risk assessment can be organized using the risk paradigm: hazard identification, exposure assessment, dose response, and risk characterization. NCEA has developed several guidelines and guidance documents for these risk assessment methodologies, both for ecological and human health. Chemical-specific risk assessments follow the risk paradigm to assess risk due to a single chemical, while site-specific risk assessments follow the risk paradigm to assess risk due to major chemicals at a particular site, where issues of mixtures would be of great concern.

As was stated in the quote above, the risk assessment process has four steps. *Hazard identification* refers to identifying the health problems caused by the pollutant. In the case of human health risk assessment, hazard identification uses both animal and human studies to establish the likelihood that a pollutant will generate harm to human health. *Exposure assessment* involves an estimation of the quantity of the pollutant that people breathe, drink, absorb through the skin, or are otherwise exposed to in a period of time. Exposure assessment also includes an estimate of how many people are exposed. In the case of air pollution, for example, exposure assessment includes measuring the quantity of air emissions from a particular source, modeling how the pollutant is transported and dispersed, estimating how many people are exposed at various distances from the emission source, and estimating the quantity of the pollutant breathed by people who are exposed. The *dose-response relationship* for a specific pollutant or human activity describes the association between exposure and the observed response (health or ecological effect). In the case of human health risk assessment, the dose-response relationship is an estimate of how different levels of exposure to a pollutant change the likelihood and severity of health effects. Just as in the hazard identification, scientists use results of animal and human studies to establish dose-response relationships. The final step, *risk characterization*, is presented in different ways to illustrate how individuals or populations in human or ecological communities may be affected.

Risk assessments play a direct role in the formulation and economic assessment of environmental policy. For example, section 108 of the Clean Air Act (CAA) directs the Administrator of the EPA to list pollutants that may reasonably be anticipated to endanger public health or welfare, and to issue air quality criteria for them. The air quality criteria are to reflect the latest scientific information useful in indicating the kind and extent of all exposure-related effects on public health and welfare that may be expected from the presence of the pollutant in ambient air. As was mentioned earlier in the chapter, environmental regulations such as those governing air quality are increasingly being evaluated using benefit/cost methodology. A good example is the EPA (USEPA 1997) study of the benefits and costs of the CAA between 1970 and 1990, which was required under the 1990 CAA Amendments. The dominant benefit identified in that study was reduced premature mortality due to reductions in particulate matter, which contributed $16.6 trillion of the estimated mean benefits of $22.2 trillion (in constant 1990 dollars), or approximately 75 percent of the total economic benefit. But how do researchers go from risk assessment of a pollutant such as particulate matter to the economic value of premature mortality prevented by regulation? The answer is the value-of-statistical-life (VSL) approach described below.

A number of different ways exist to estimate the economic value of a statistical premature death avoided due to environmental regulation. Most of these use information on people's willingness to pay for a reduction in the probability of premature death. For example, one can use survey methods to solicit hypothetical willingness-to-pay information from respondents (described in greater detail in the section on contingent valuation) regarding changes in the likelihood of premature death. One can also conduct wage-risk studies to estimate the additional compensation demanded in the labor market for riskier jobs. In particular, when jobs are similar in most all respects except that one entails a higher risk of some harm, then competitive labor markets (with well-informed workers) are expected to yield a "wage premium" paid to those workers who accept the higher risk of premature death or workplace injury. Naturally, these wage premiums may not be observed if some workers are misinformed of risk, the labor market is not competitive, or if some people are naturally less averse to risk than others. In one example of a wage premium, Olson (1981) estimated that, all else being equal, a 10 percent increase in the probability of a nonfatal workplace accident is associated with a 9.1 percent increase in wage. Workers in jobs of average risk—1 in 30 of a nonfatal accident—received on average $2,200 more per year in income when compared to workers with similar educational attainment in virtually riskless jobs. These numbers can be translated into the value of a statistical life, as will be shown below.

Let us see how wage premiums paid for accepting riskier work environments can be used in the VSL approach. Suppose that a wage-risk study estimates that when the annual risk of premature death on the job increases by 0.0001 (1 in 10,000), workers receive an annual wage premium of $550 as compensation for this added risk. Assume that all other work characteristics are held constant. If we assume that those workers are fully informed and the labor market is competitive, then we can expect the following equation to hold:

Wage premium = (value of statistical life) × (increased probability of death).

Thus, with a bit of algebraic rearranging, we get:

Value of statistical life = (wage premium) ÷ (increased probability of death).

Plugging in an increased probability of death of 0.0001 and a $550 wage premium we arrive at a value of a statistical premature death avoided of $5.5 million.

Based on 26 wage-risk and hypothetical willingness-to-pay studies, the EPA (USEPA 1997) estimated a mean value of a statistical premature death avoided to be $4.8 million (in constant 1990 dollars). Controversy surrounds the VSL approach used by the EPA (USEPA 1997). For example, while most of the 26 studies used by the EPA in arriving at the VSL figure of $4.8 million involved the value of risks to middle-aged working people, those who die prematurely from particulate matter are more likely to be aged and past their working years. Moreover, job-related risks are more likely to be borne voluntarily and to involve the risk of sudden and catastrophic death, whereas pollution-related risks are borne involuntarily and involve the risk of longer periods of disease and suffering.

Other controversies regarding the VSL approach have to do with differences in wages and earnings between rich and poor countries. In poor countries with low wages, labor markets will pay smaller wage premiums for a given increase in risk of death than in rich countries, implying that a statistical life is more valuable in a rich country than in a poor country. As mentioned at the start of the chapter, the study by Bowland and Beghin (1998) offers a good example of VSL differences across rich and poor countries. They estimated that the value of a statistical life saved in Santiago, Chile, due to reduced air pollution is approximately $600,000, which is only about 12.5 percent of the $4.8 million value of an American statistical life used by the EPA (USEPA 1997). The logic of BCA might then suggest locating hazardous life-threatening industrial activity and toxic wastes in the poorest regions of the world, which many would consider an unacceptable example of environmental injustice. Though many problems exist with the VSL approach, simply ignoring the economic cost of premature death and leaving it out of BCA leads to a substantial underestimate of the benefits of environmental conservation and restoration.

An alternative approach taken by Tengs et al. (1995) is to evaluate the cost of regulatory intervention per statistical life-year saved by the intervention. This type of analysis allows policymakers to allocate regulatory resources to those interventions that generate the most statistical life-years saved per dollar of intervention. To arrive at cost per statistical life-year saved, Tengs and her colleagues took the total cost of a regulatory intervention and divided by the number of statistical life-years saved by that intervention. They found, for example, that the cost per statistical life-year saved was only $69 for mandatory seat belt use laws, but was $920 for mandatory smoke detector laws. Chlorination of drinking water generated a cost per life-year of $3,100. Banning asbestos water pipe insulation generated a cost per life-year of $65,000, while banning amitraz pesticide use for pears generated a figure of $350,000 and the ozone-control program in southern California generated a cost per life-year of $610,000.

In addition, banning asbestos in packing generated a cost per statistical life-year saved of $5 million, and seismic retrofitting of buildings in earthquake-prone areas generated a cost per life-year of a whopping $18 million. It is important to note that the approach taken by Tengs et al. (1995) assumes that the saving of statistical life-years is the only benefit produced by the regulatory intervention, when in fact preventing premature death is only part of the benefit of many of these regulations. Nevertheless, their work offers useful guidance on the most cost-effective ways to save lives through regulatory intervention. It also illustrates how risk assessment can be used to provide information on the cost-effectiveness of various regulatory interventions without having to establish a particular value of a statistical life.

Although quantitative risk assessment (QRA) is a method for measuring the statistical impact of environmental and other regulations affecting human and ecosystem health, other methods have been developed for measuring the benefits of preserving recreation and wilderness areas and for measuring the risk-free benefits of producing a cleaner and more desirable environment. As we have already discussed how to measure market impacts, we will now focus our attention on several methods of measuring nonmarket impacts.

Categories of Nonmarketed Environmental Benefits: Use and Nonuse Values

Use Values

Use value represents the utility enjoyed by people who directly use some aspect of the environment. For example, a bird sanctuary yields use value to bird watchers and to those who use the area as an open space (walking, jogging, observing the view). Likewise, a backcountry area provides use value to hunters, hikers, backpackers, and equestrians, and the ocean shore provides use value to surfers and fishers.

Nonuse Values

Nonuse values, also known as *passive-use values* or *existence values,* reflect value that people assign to aspects of the natural environment that they care about but do not use in a commercial, recreational, or other manner. For example, someone might value the existence of grizzly bear habitat in Alaska but have no interest in actually visiting such wildland habitat. Existence values are controversial because they are difficult to measure. As we will see in the next section of the chapter, survey research methods have been developed to measure nonuse values. One type of nonuse value is *option value,* which is prominent when (1) there is uncertainty over the ultimate environmental impact of a given activity that (2) is irreversible. The classic example is large-scale tropical rain forest destruction, where thousands of species of plants and animals are made extinct before people even understand them and their possible beneficial role in medicine, foodstuffs, and so forth. Preservation has option value—it gives us time to learn about the possible services that are provided to people by the rain forest. Another is greenhouse gas production, where changes in the atmosphere are irreversible on the scale of human generations, and both the extent and the ultimate impact of global warming are not fully known. There is an option value to controlling greenhouse gas emissions today until we learn about their impact on our life-support systems.

Measuring Nonmarketed Environmental Benefits: The Contingent Valuation Method (CVM)

The contingent valuation method (CVM) involves the use of survey questionnaires to elicit hypothetical willingness-to-pay information. The CVM was first proposed by Ciriacy-Wantrup (1947), who recognized that some aspects of soil erosion (e.g., clogging of shared irrigation channels) have the attributes of a negative externality that is not borne as a cost by the individual farmer. He did not actually conduct a CVM. The first actual CVM study was done by a Harvard doctoral student (Rob Davis) in his dissertation, where he attempted to value nonmarketed aspects of the Maine woods (hunting and recreation values). In his study, he compared the results of the CVM against the travel cost method (described below) for the same area and found that the two methods arrived at remarkably similar valuations. Finally, because CVM studies are one of the few ways to measure nonuse values, CVM studies became popular following the publication of a highly influential paper by environmental economist John Krutilla (1967) that endorsed the “real” nature of existence and other nonuse values.

An important event that hastened the development of best methods in contingent valuation was the damage assessment following the March 1989 *Exxon Valdez* oil spill disaster in Prince William Sound, Alaska. The description that follows borrows heavily from Portney (1994). The oil tanker *Exxon Valdez* struck Bligh Reef in Prince William Sound and punctured its hull, causing 11 million gallons of crude oil to spill into the ocean. A CVM analysis was conducted by Carson et al. (1992) for the State of Alaska to determine lost existence value for U.S. residents. The analysis by Carson et al. yielded an estimated $3 billion in lost existence value. In 1991, a lawsuit by the federal government and the State of Alaska against Exxon was settled for $1.15 billion. Because the case was settled out of court, it is impossible to know whether the study by Carson et al. (1992) influenced the size of the settlement. The federal Oil Pollution Act of 1990 was passed in response to the *Exxon Valdez* oil spill, and a part of this legislation directed the National Oceanographic and Atmospheric Administration (NOAA) to draft regulations governing damage assessment. Environmentalists pressured NOAA to have lost nonuse values be fully compensable damages and to use the CVM to measure them. Oil companies and others strongly lobbied against the inclusion of nonuse values and the CVM in damage assessment.

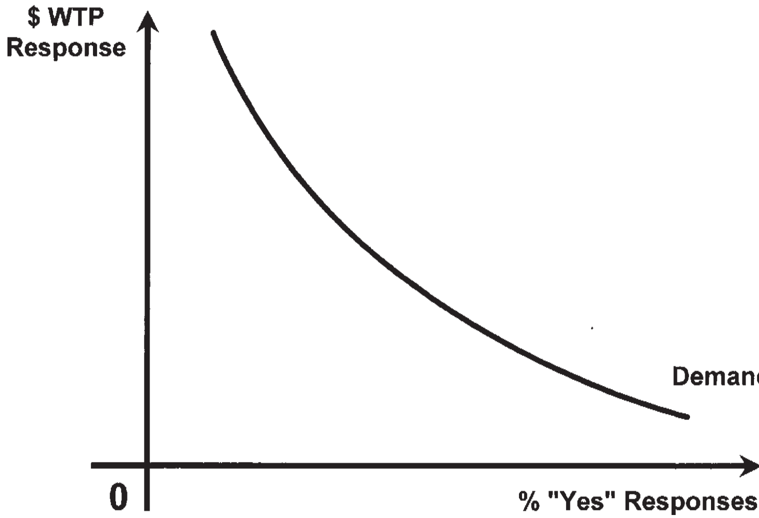
In response to these conflicting pressures, NOAA asked Nobel laureates Kenneth Arrow and Robert Solow to chair a panel of experts (including Paul Portney) to advise NOAA on the CVM. The agency wanted an answer to the question of whether the CVM is capable of providing estimates of lost nonuse values that are reliable enough to be used in natural resource damage assessments. The NOAA panel completed its report in early 1993.

The NOAA panel concluded that CVM analysis, conducted appropriately, “can produce estimates reliable enough to be the starting point of a judicial process of damage assessment, including lost passive-use values.” But what was the panel’s view of an appropriately conducted CVM study? Panel members established a set of guidelines for future CVM studies aimed at producing reliable estimates for lost existence values for the purposes of damage assessment or regulatory policy. These guidelines have contributed to the development of the modern CVM survey, which is organized as follows:

1. Clearly identify the contingency to be studied. In the case of estimating lost existence values in damage assessment, the NOAA panel guidelines call for eliciting willingness to pay (WTP) to prevent a future incident rather than the minimum compensation required for damages that have already occurred. Examples of environmental or resource contingencies include land management policy or river and stream habitat restoration.
2. Perform a pretest in which you survey a small focus group. The pretest can be used to identify problems with the survey instrument and to determine the likely range of WTP values.
3. Use these preliminary values to make up a survey instrument. The survey instrument must accurately and understandably inform people of the precise nature of the anticipated effects of the contingency. The survey instrument must use a referendum-style format in eliciting WTP information. A *referendum* is a vote in which people are asked to make a dichotomous choice (yes or no) regarding a political question. Therefore, the survey should ask respondents how they would vote if faced with a referendum proposal in which the specific environmental improvement is to be paid for by a specific increase in taxes or higher product prices. As Portney (1994) observed, the NOAA panel reasoned that people are frequently confronted with decisions involving specific posted prices, and that stated responses are more likely to reflect actual valuations than if confronted with an open-ended question asking maximum WTP.

   Moreover, the survey instrument must remind respondents that an affirmative WTP response reduces funds that the respondent will have to spend on other goods and services. The survey instrument must remind respondents of the availability of substitutes for the environmental improvement being proposed. For example, if the CVM is evaluating WTP to enhance salmon habitat in a stream, the survey instrument should inform respondents of other stream habitat that already exists. The survey instrument should include follow-up questions to ensure that respondents understood the issues and questions in the survey, and to determine the reasons for their response.
4. Use repeated random sampling techniques with a different dollar amount for each random sample of people to be surveyed. The

Figure 6.3 **Contingent Valuation Method**



NOAA panel guidelines call for the use of personal interviews rather than telephone interviews when possible. Telephone interviews are considered to be preferable to mail surveys.

5. Analyze the data using relevant statistical techniques to estimate a demand curve (WTP function), which relates percentage of "yes" responses to each of the surveyed WTP values, holding other reported factors such as income, age, gender, education, and concern for the environment constant.

One would normally expect that the higher the WTP value asked to one of the random samples of people, the smaller will be the frequency of "yes" responses. Thus, if one plots WTP on the *y* axis and frequency of "yes" responses on the *x* axis, one would expect to observe an inverse relationship in the responses to the questionnaire. Thus, one can estimate a demand curve for the environmental amenity under analysis by relating WTP values to percentage of "yes" responses, as shown by the generic curve in Figure 6.3. An estimate of consumer surplus—the net economic value of the environmental improvement—can then be derived from this demand curve.

Examples of CVM Studies

Loomis (1996) performed a CVM study on the benefits of removing dams and restoring the Elwha River in Washington State. Loomis used a modern dichotomous-choice voter referendum form of CVM study to obtain estimates of WTP for removing two dams on the Elwha River in Washington's Olympic Peninsula and restoring the ecosystem, with particular attention to the benefits of enhancing the salmon runs. Loomis found that mean annual value per household was estimated to be $59 in Clallam County, Washington, and $73 for the rest of the state. The aggregate benefits to the residents of Washington were estimated to be $138 million annually for ten years.

Loomis (1987) used the CVM to quantify nonmarketed environmental benefits from enhancing natural aquatic conditions. In this case, the problem was to determine the public trust values of Mono Lake at alternative lake levels. Loomis found that the economic benefit to California residents of preserving Mono Lake could conservatively be estimated to be $1.5 billion annually. Purchase of replacement water and power would cost Los Angeles $26.2 million per year. Thus, on efficiency grounds the reallocation of water for maintenance of public trust values in Mono Lake could be warranted.

California has lost more than 90 percent of its historic wetlands, the largest percentage of any state in the union. Allen et al. (1992) surveyed the literature to determine low, median, and high valuations for the various "services" provided by wetlands, including flood control, water supply, water quality, recreation, commercial fisheries, and wildlife habitat. Their overall median annual benefit was estimated to be $9.96 billion.

Schultze et al. (1983) used the CVM to study the economic benefits of visual quality in the Grand Canyon. Visibility in the Grand Canyon and other nearby natural areas was impaired by a large coal-fired electricity-generating plant. Schultze and colleagues surveyed residents of Albuquerque, Denver, Los Angeles, and Chicago to determine the maximum a household would be willing to pay in higher entry fees or higher utility bills to maintain the park's visual quality. The average figure was $7 to $10 per month per household, leading to an aggregate estimate (taking into account socioeconomic household characteristics) of $6 billion per year. Note that for 99 percent of the households, these represent "existence" values rather than direct consumption values, as only about 1 percent visit the parks—an indication of the important role of nonuse values.

Walsh et al. (1982) used the CVM to determine how much people value allocating an additional 2.6 million acres as federal wilderness in Colorado. Their survey was designed to gain insight into the relative importance of key value areas—use, option, and existence. On average, recreation was worth $18.50 per visitor-day—yielding a total of $28 million annually. Passive-use values (existence, option) totaled $135 million per year. This totals into the billions when one calculates present value of this stream of benefits into the future.

The CVM Debate

Despite the advances that have occurred in CVM technique, economists are somewhat divided over the usefulness of the CVM in measuring value and guiding policy. The *Journal of Economic Perspectives* published a symposium on the usefulness of the CVM in its fall 1994 issue. A number of the points raised in that symposium by Diamond and Hausman (1994) and Hanemann (1994) are summarized below.

A key problem with CVM analysis, as claimed by Diamond and Hausman (1994), is the *embedding effect*. "Embedding" refers to the research methodology of comparing the value of a particular good, such as protection of a mountain lake, to a more inclusive good, such as protecting an entire mountainous region that includes the lake. The embedding effect occurs when WTP responses for the particular good (protecting the mountain lake) are approximately equal to the WTP responses for the more inclusive good (protecting the entire mountainous region). Diamond and Hausman (1994) observe that the embedding effect arises from the nonexistence of individual preferences for the good in question and from the failure of respondents to consider the effects of their budget constraints in hypothetical WTP surveys. Hanemann (1994) disputes the argument by Diamond and Hausman (1994) that CVM studies are prone to embedding effects. Hanemann observes that the studies used by Diamond and Hausman (1994) in making their argument violate the NOAA panel guidelines in a number of important ways, and therefore argues that the evidence for the embedding effect does not apply to properly conducted CVM studies. Diamond and Hausman (1994) state that "embedding still infects even very recent work done by experienced contingent valuation analysts who were well aware of the problem" (p. 52), and they conclude that the embedding effect implies that responses in CVM studies reflect "warm glow" feelings rather than true WTP.

Another problem identified in some CVM studies is a difference in responses between WTP for an environmental improvement and WTP payment in return for giving up the environmental improvement. Economic theory suggests that WTP and willingness-to-accept (WTA) should be nearly the same, differing slightly due to income effects. Usually, WTP is considerably less than WTA for the same environmental improvement, which is inconsistent with the economic theory of consumer choice. Hanemann (1994) observes that the WTP–WTA gap is seen in CVM studies that violate the NOAA panel guidelines by using "open-ended" payment questions that solicit the respondent's WTP rather than a "closed-ended" fixed WTP value in referendum format, in which respondents are given the dichotomous choice of either accepting or rejecting.

All surveys are vulnerable to *response effects*, in which small changes in wording or order of survey questionnaire material can cause significant changes in survey responses. Hanemann (1994) states that "surveys, like all communication, are sensitive to nuance and context and are bound by constraints of human cognition" (p. 27). Nevertheless, surveys are a central source of data for "traditional" economic analysis and include the Current Population Survey, Consumer Expenditure Survey, Monthly Labor Survey, and Panel Study on Income Dynamics. Hence, if these sort of response effects are a reason to cast doubt on CVM studies, they should also cast doubt on the large number of other survey-based data sets used by economists.

Another criticism of the CVM is that the survey process itself creates the values reported as empirical data—people just make something up when asked. The standard view of rational humans in economics is based on individuals' having a preexisting valuation map in their heads that ranks all the possible choices available in contemporary markets, yet as Hanemann (1994) points out, this view is inconsistent with much of the contemporary research in cognition. The issue is whether the preferences are stable, and recent studies support this (comparing values over time).

One can also argue that there is the potential for *strategic bias* in CVM survey data, in which people may inflate their stated values because they do not have to "put their money where their mouth is." This is one of the reasons why the NOAA panel called for closed-ended referendum-style WTP questions. Moreover, some referendum-style CVM studies have compared the hypothetical responses to actual parallel referenda and have found that in modern CVM studies there is often no significant difference in responses. See the "cannot be verified" criticism below.

Critics of the CVM also argue that ordinary people are ill-trained for valuing the environment in a referendum-style format. Note, however, that training is not a criterion for voting in democratic systems, and one could make the argument that there is at least a core of rationality in voter behavior.

Critics also argue that CVM survey responses cannot be verified. This statement is not always true. Survey responses can be validated through replication, comparison with estimates from other sources, and comparison with actual behavior. Hanemann (1994) reports that there are now more than 80 studies offering comparisons of CVM with other methods; overall, CVMs typically are somewhat lower than values elicited using other indirect techniques. When the CVM is compared to actual spending, say with user fees, CVMs generally are very close to the actual spending level, and CVM referendum "yes" rates have been found to be slightly lower than when the issue was actually placed on the ballot (Carson et al. 1986; 70–75 percent in CVM versus a 73 percent "yes" rate for a water quality referendum in California in

1985). Similar verification has been provided in comparisons of CVM responses with actual voluntary contributions (Sinden 1988).

In addition to the problems with the CVM, there is also the problem of whether people understand the ecosystem function of the particular aspect of the environment subject to the CVM analysis. The ecosystem role of an element of the environment may not be known unless or until it is destroyed. It is also clear that many people do not want to participate in a process of monetizing the environment, just as Christians would not want to monetize the value of their faith.

Measuring Nonmarketed Environmental Benefits: The Travel Cost Method (TCM)

The travel cost method (TCM) was first proposed by economist Harold Hotelling in a 1947 letter to the U.S. Park Service, in which he suggested that the full cost of visiting a park must necessarily include the cost of getting there. The TCM is useful for measuring active-use values of place-based aspects of the environment such as lakes and wilderness areas used for recreational purposes. The TCM offers a way measuring the value of a nonmarketed recreational resource by using data on the travel costs incurred by people who visit the area. If we assume that recreationalists do not later regret their trip, then voluntary expenditures on travel to arrive at a recreational area are a measure of what people are willing to pay to visit and actively utilize a park or recreation area.

The TCM only measures economic benefits from recreational visitors, and thus ignores existence values. Moreover, as Randall (1994) and others have observed, an individual's opportunity cost of travel time is inherently unobservable, and so the researcher must make a number of assumptions in order to generate a dollar-denominated measure of benefits. Researchers using the TCM must either assume that the study area was the sole purpose of the travel, or conduct their own survey and ask each individual to estimate the portion of their travel that is attributable to the study area. On the one hand, remote wilderness areas are more likely to elicit single-purpose travel than, say, state parks along interstate highways, but on the other hand, many visitors are likely to visit no more than once during the study period. The latter implies that individual visitation may not vary with travel cost, making it difficult to estimate recreational demand based on individual visitor data. The zonal method, which utilizes existing wilderness permit data and explains visitation from geographical zones of origin, may be appropriate in such circumstances. The zonal method will be described below. Readers interested in the individual observation survey approach should consider Loomis and Walsh (1997) for an accessible survey.

The U.S. Water Resources Council (1983) provides guidelines and procedures for the zonal TCM, and Loomis and Walsh (1997) offer a detailed description of how to conduct such a study. To illustrate these procedures, assume that the subject of analysis is the recreational economic value of a wilderness area. The procedure calls for aggregating individual visitation in the primary data set by county of origin listed on the wilderness permit. Because many people only visit wilderness areas once a year, making it difficult to estimate individual visitor demand curves using travel-cost prices, the zonal TCM explains the fraction of each county's population that visits the study area as a function of travel cost. Thus, each observation in the final data set is made up of information on per capita visitation, income, and travel cost from a county zone of origin. Wilderness permits do not record whether or not the wilderness recreation was the sole purpose of the travel. Loomis and Walsh (1997) argue that one method of mitigating for multiple destination travel is to choose a geographical boundary for the recreational site that serves as the "market" for the recreational experience. People who travel from extraordinarily long distances are more likely to be on multidestination vacation trips. A standard procedure in accordance with federal guidelines is to include all zones of origin that together account for approximately the nearest 95 percent of all visitors, assuming that the approximately 5 percent representing the most distant visitors are on multidestination trips. These observations are excluded from the travel cost analysis, and their benefits are assumed to be equal to the average of those in the analysis.

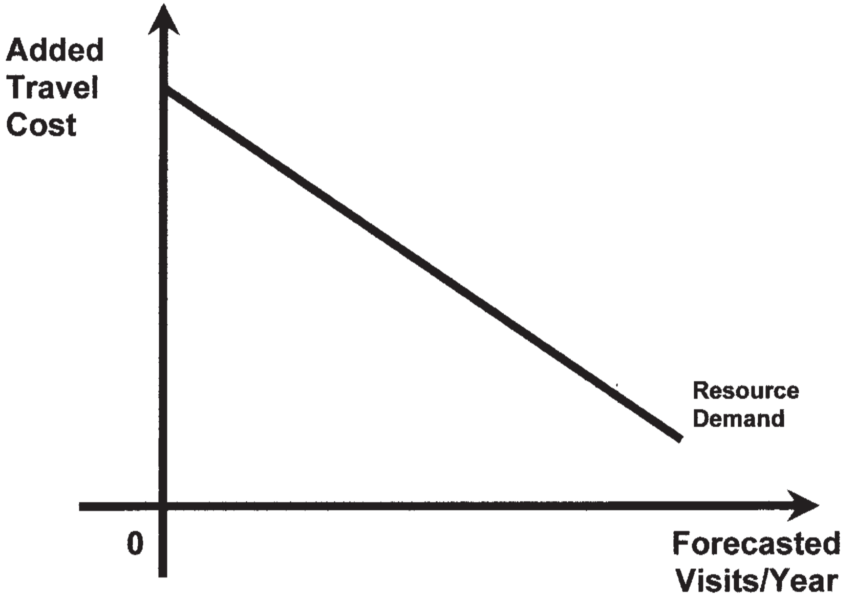
Several other assumptions are made in this zonal travel cost analysis. One of these assumptions is that characteristics of the population not quantified and included in the study are the same across the various zones of origin. It is common to include demographic variables such as per capita personal income. Another assumption employed in the zonal TCM is that wilderness visits are of equal duration. Because each observation in the final data set is a county zone of origin, it is not possible to include data on visit duration from individual permits. It is usually assumed in the zonal TCM that visitors travel by way of automobile, that all visitors listed on a given permit travel together, and that each visitor has the same opportunity cost of an hour in transit. Finally, as wilderness permits only record the point of origin for the person filling out the permit, it is assumed that all individuals listed on a given permit travel from the county zone of origin indicated on the permit.

An individual's direct travel cost from his or her county of origin to the study area is the sum of the person's share of direct automobile transportation cost and an estimate of the value of time spent in transit. One source for direct automobile travel cost is the *Transportation Energy Data Book*; according to this source, in 1999 the average variable cost per mile of operating an automobile in the United States was given as $0.1058 (Oak Ridge National Laboratory 1999). It is assumed that each member of the party listed on a wilderness permit travels together in a single vehicle and they equally share the transportation cost. As a result, the transportation cost from the county zone of origin to the study area is $0.1058 times the round-trip mileage from the county seat of the county zone of origin, divided by the average number of visitors listed on the permit. Round-trip mileage can be found using geographical information system data or travel route mapping services. The other part of travel cost is the value of time in transit. Loomis and Walsh (1997) observed that drivers appear to value their travel time at between one-quarter and one-half of the relevant hourly wage rate. As a result, round-trip travel time from the county seat of the county zone of origin is multiplied by the appropriate hourly rate to arrive at the opportunity cost of time in transit.

In addition to the travel cost measure of price, one should also include per capita income data and a travel-cost measure of the price of visiting substitute recreational areas when estimating the demand curve for the recreational resource. The substitutes should be similar in quality and within the relevant market defined for the study area. As outlined by the U.S. Water Resources Council (1983), the zonal TCM derives economic benefits using a two-stage process. First, regression analysis is used to estimate a demand function for the resource in question. Second, progressively higher travel costs to the study area are introduced to the estimated demand function to derive a set of forecasted visitation levels from each county zone of origin. These forecasted visitation levels are horizontally summed at each increment of additional travel cost, with the result being the final resource demand curve, such as the one shown in Figure 6.4. The area under the resource demand curve represents the net economic benefits that flow annually to recreational visitors to the study area

Let us take a moment and consider the results of some TCM studies. Hackett (2000) used the zonal TCM to estimate the recreational economic value of the Trinity Alps Wilderness of northwestern California. His zonal travel cost analysis indicates that visitors receive an average of $29.38 in net recreational economic benefits, as measured by estimated consumer surplus, from a visit to the eastern Trinity Alps. Englin and Shonkwiler (1995) applied a variant of the TCM using individual visitor survey data to assign an economic value to hiking in the Cascade Mountain range of Washington and Oregon. Their preferred estimate was that an average hike generated between approximately $16 and $24 (1985 dollars) in net benefits. Using similar methodology, Casey et al. (1995) estimated mean consumer surplus per visit of approximately $513 for hiking in the Grandfather Mountain Wilder-

Figure 6.4 **Resource Demand Curve Estimated from TCM Analysis**



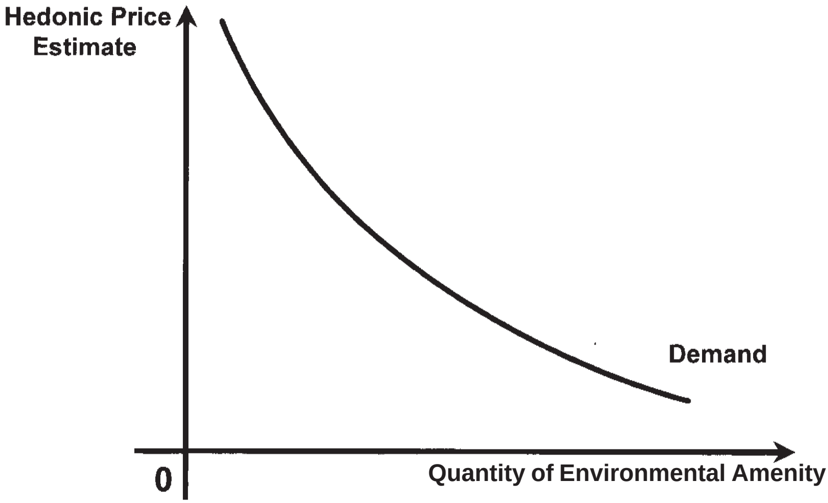
ness Preserve in North Carolina. This large value for consumer surplus occurs in part because the opportunity cost of time revealed by individual visitors was quite high, averaging nearly $47 per hour.

Bell and Leeworthy (1990) used the individual survey approach to estimate the recreational economic value of Florida's beaches. They gathered data on days spent on the beach, expenses incurred while visiting, the cost of their travel to Florida, as well as other factors that influence visiting the beach such as age, number of children, income, and perceived quality of such an experience. Using the statistical technique of multiple regression analysis, they were able to isolate the impact of travel cost and number of beach visits. The average tourist spent nearly five days on the beach and spent on average $85 per day. From this information, Bell and Leeworthy estimated average daily consumer surplus of $38. With 70 million tourists annually visiting Florida beaches, these areas were found to yield a lower-bound estimate of $2.7 billion annually in active-use value.

Measuring Nonmarketed Environmental Benefits: Hedonic Regression Method (HRM)

In some cases environmental qualities can be inferred indirectly from the way they change the value of complementary goods that are traded in mar-

Figure 6.5 **Hedonic Regression Method**



kets. This is how the hedonic regression method (HRM) works. The word *hedonic* as used here refers to pleasure and reflects the desirable or quality aspect of otherwise nonpriced aspects of the environment. The classic example of this method is the effect on residential home values of quiet, stable neighborhoods with fine views, low crime, easy commutes, and little in the way of smog. These community and environmental qualities are "consumed" along with the services of the home and so are complementary "services" that are not directly marketed. Real estate prices in such neighborhoods are substantially higher than for otherwise comparable homes in areas with lower environmental and community values. The term *regression* in the HRM refers to a statistical technique by which data on the prices of marketed objects such as homes are explained by characteristics of the home as well as measures of environmental, neighborhood, and community qualities. Thus, we might learn that a 10 percent lower crime rate or level of smog might result in a 15 percent increase in the value of a home, holding all the other quality characteristics constant.

Hedonic regression studies reveal willingness to pay for environmental, health, safety, and community qualities. We would hypothesize that as the estimated hedonic price of these qualities falls, more and more people would be willing to pay to get them. In this case we could estimate a type of demand curve for a particular level of environmental and other qualities, as shown generically in Figure 6.5.

Consider some examples of the use of the HRM. Pollard (1982) found that, holding other characteristics constant, Chicago apartments with views of Lake Michigan commanded on average a 26 percent rental price premium. Given that housing typically accounts for 20–25 percent of an individual's income, the amenity value of scenic beauty was worth a sacrifice of 5–6 percent of overall income. Grimes (1983) estimated that land fronting on Lake Michigan sold at prices twice as high (on a per acre basis) as land just 500 feet inland. As the distance from the lake increased to 1,500 feet, the value fell to one-fifth of lakefront property. Brown and Pollakowski (1977) found that, holding constant other factors such as house size and age, on average a house within 300 feet of Lakes Washington, Green, or Haller in the State of Washington, commanded a price premium of approximately $24,800 (1993 dollars) relative to houses farther away from the lakes. Brookshire et al. (1982) estimated that the hedonic value of clean air in the Los Angeles area was approximately $381 (1993 dollars) per month for locations with more direct access to fresh air off the Pacific Ocean (not necessarily beachfront). Diamond (1980) estimated that approximately 7.5 percent of the value of a home in Boston was based on the crime characteristics of its location. (Note: Power [1996] offers a nice survey of this literature in his book, where he uses HRM analyses to demonstrate the importance of quality in economic decision making.)

We have discussed issues relating to measuring the benefits of protecting and enhancing the natural environment. Such measurement is of course critical to BCA. Benefits measurement is also used by those sympathetic to environmental protection to influence the political process. For example, CVM survey data may result in a particular environmental initiative being placed on a ballot, or it may force state or federal resource management agencies to acknowledge the value of certain environmentally prominent areas. We will now turn to the subject of measuring and assessing the costs of providing an improved environment.

Measuring Costs

The cost of environmental regulation can be divided into direct and indirect costs. *Direct compliance costs* include pollution abatement and expenditures by firms, consumers, and government, as well as opportunity costs that can be attributed directly to regulation. Firms bear direct compliance costs for such things as pollution-control capital equipment and pollution-control operating costs (more environmentally or resource-friendly methods, materials, and specialized personnel). Because capital expenditures yield a flow of benefits over time, capital expenditures must be amortized over the useful life of the capital equipment to arrive at an annualized cost. Consumers bear direct compliance costs for things like vehicle inspections and water conservation devices. Local, state, and federal governments bear direct compliance costs for activities such as the drafting of regulations, and the monitoring, oversight, and enforcement of those regulations. Firms, consumers, and government also bear opportunity costs that should be included as direct compliance costs. For example, when regulations add new restrictions to timber harvest on environmentally sensitive land, the landowner must forgo revenue, and this lost revenue is an opportunity cost that should be included in a complete accounting of regulatory cost. Likewise, new regulatory mandates imposed on a regulatory agency with a fixed budget will require that some existing regulatory activities will need to be reduced, and the lost benefits of reduced regulatory activity in some other area should also be included in a complete accounting of regulatory cost.

There are also various *indirect costs* that result as feedback effects from environmental regulation. For example, regulations that raise a firm's marginal costs will cause higher market prices and thus change the composition of goods and services produced in the economy. Resources allocated to purchase pollution abatement and control equipment may have otherwise gone to investment in productivity-enhancing innovation, yielding an opportunity cost of a slower rate of economic growth. Higher fixed regulatory costs will increase the level of output required for a firm to cover fixed costs and break even, which can lead to a reduced number of companies and a diminishment of the competitive process.

A full accounting of regulatory cost is difficult and requires a certain number of assumptions about things such as the degree of compliance and the nature and extent of cost-reducing innovations in pollution-control and other environmentally friendly technologies. Moreover, in practice it is difficult to measure opportunity cost. For example, how does one measure the opportunity cost of, say, $1 billion spent by the federal government in monitoring and enforcement effort? What is given up by society might include reduced taxes and increased personal consumption spending, investment in other wealth-generating activities, or spending in other budget areas such as defense or law enforcement or health or education. Both direct and indirect effects will be discussed below.

Direct Costs

Up until 1995, the U.S. Department of Commerce reported on the cost of pollution abatement and control expenditures (PACE) (omitting opportunity costs) in its *Survey of Current Business* (Rutledge and Vogan 1995). Unfortunately, the Department of Commerce has discontinued this report. The most recent Census Bureau data are for 1994 (U.S. Bureau of the Census 1996).

Table 6.2

Pollution Abatement and Control Costs in the United States, in Billions of Inflation-Adjusted (1987) Dollars

Category	1987	1988	1989	1990	1991	1992	1993
Air	28.9	30.2	27.4	25.8	24.5	26	28
Water	30.2	30.1	31	33.5	33.1	33.9	33.5
Solid waste	19.1	21.2	24.1	26.2	27.2	29	30.7

Source: Rutledge and Vogan (1995).

PACE is divided into spending on pollution abatement (about 90 percent of total PACE), government regulation and monitoring, and research and development ([R&D]; the latter two are about 10 percent of total PACE). Rutledge and Vogan (1995) estimate that inflation-adjusted PACE in the United States for 1993 was $91.8 billion, an increase of 4.7 percent from 1992. In current (unadjusted) dollars, 1993 PACE was estimated to be $109 billion. As inflation-adjusted PACE spending has been growing faster than real gross domestic product (GDP), the share of GDP coming from PACE spending increased and was estimated to be 1.8 percent in 1993. This represents a slight increase from the 1.7 percent of GDP that was estimated for PACE in 1987. The private business sector accounts for two-thirds of the total spending on the pollution abatement element of total PACE. Spending on government regulation and monitoring represents a declining share of total PACE, but even larger is the decline in PACE on R&D (inflation-adjusted spending on R&D fell 12.7 percent from 1992 to 1993). Inflation-adjusted PACE for air pollution and solid-waste disposal both increased by about 7 percent from 1992 to 1993.

Table 6.2 shows inflation-adjusted (constant 1987 dollars) PACE by major category, in billions of dollars, from Rutledge and Vogan (1995).

The U.S. Bureau of the Census (1996) reports on capital expenditures for stationary-source pollution abatement and control (capital PACE) by manufacturing facilities with at least 20 employees. The Bureau states that capital PACE for these large manufacturing firms was $7.88 billion in 1994; approximately 73 percent of this total was concentrated in four industry groups: chemicals and allied products; petroleum and coal products; paper and allied products; and primary metal industries. Three states (California, Texas, and Louisiana) accounted for 35 percent of capital PACE by large manufacturing firms. Operating expenditures for pollution abatement and control (operating PACE) by manufacturing facilities with at least 20 employees was $20.67 billion in 1994. Capital PACE by nonmanufacturing industries in 1994 was $551 million for the mining industry, $4.66 billion for the petroleum and coal industry, and $4.35 billion for the electric utility industry.

The EPA (USEPA 1990) reports on both capital PACE and operating PACE for mobile sources of air pollution. Mobile-source PACE is primarily from automobile regulation, including the capital and maintenance costs of pollution abatement equipment, fuel price and efficiency effects, and the cost of inspecting automobiles. The 1990 EPA report showed that the sum of capital and operating PACE for mobile-source air pollution was $7.3 billion in 1990. The EPA also provides the following annualized estimates of U.S. pollution-control costs (USEPA 1990):

- *Air:* Increased from $9.2 billion in 1972 to $43.5 billion (estimated) in 1995.
- *Water:* Increased from $11.5 billion in 1972 to $62.5 billion (estimated) in 1995.
- *Land:* Increased from $9.8 billion in 1972 to $43.5 billion (estimated) in 1995.
- *Chemicals:* Increased from $100 million in 1972 to $2.9 billion (estimated) in 1995.
- *Other:* Increased from $100 million in 1972 to $2.5 billion (estimated) in 1995.
- *Total:* Increased from $31 billion in 1972 to $161.2 billion (estimated) in 1995.
- *Percentage of gross national product (GNP):* Increased from 0.9 percent in 1972 to 2.6 percent (estimated) in 1995.

Viscusi (1996) reports that of the estimated $500 billion in annualized regulatory costs in the U.S. economy from all forms of regulation, about one-half are attributable to paperwork costs. Of the estimated $200 billion in annualized direct regulatory costs to business and elsewhere, about one-half can be attributed to environmental regulations.

The EPA (USEPA 1990) estimates for 1995 are based on 100 percent compliance, which means that they may be somewhat overstated. Major increases in the cost of environmental regulation have occurred in conjunction with the stricter requirements for clean air and water and for “Superfund” site remediation (especially the legal wrangling over who is responsible for cleanup costs).

Indirect Costs

In addition to direct costs, environmental regulations also impose various kinds of indirect costs, which include both macroeconomic and microeconomic impacts. The EPA (USEPA 1997) reports on estimated macroeconomic impacts from the Clean Air Act (CAA) during the period from 1970 to 1990. These impacts were estimated from a general-equilibrium economic model that evaluated the feedback effects of the CAA regulatory controls relative to a hypothetical no-control scenario. Macroeconomic impacts are grouped into two broad classes: sectoral impacts and aggregate impacts. The EPA reports that compliance with the CAA had the greatest sectoral impacts on large energy producers and consumers, particularly those sectors that relied most heavily on consumption of fossil fuels. Production costs increased more for capital-intensive industries than for less capital-intensive industries owing to a projected increase in interest rates, which were projected to have been increased by the CAA because the CAA required significant investment in capital PACE that expanded the demand for loanable funds. Indirect regulatory impacts on the electric utility industry were estimated to have generated a 2 to 4 percent increase in consumer prices and a resulting 3 to 5 percent reduction in output by 1990. Many other manufacturing sectors saw an output reduction effect in the 1 percent range. A key aggregate impact of the CAA was an estimated one twentieth of 1 percent per year reduction in economic growth due to CAA-mandated investment in capital PACE, reducing the level of investment available for capital formation. Consequently, GNP was estimated to have been reduced by a total of 1 percent ($55 billion) relative to the no-control scenario.

There are also potential microeconomic impacts on certain capital-intensive industries. Environmental regulations may not only increase the cost per unit (e.g., per piece of furniture, per BTU of electricity), but perhaps more important they increase *fixed costs* (those costs that do not vary with how much a firm produces, such as scrubbers on smokestacks). When fixed costs increase substantially, it requires that a firm have a larger output level to maintain profitability. Thus, large fixed costs can lead to market structures with fewer, larger firms (increased market concentration). Firms gain larger market shares because each is compelled to expand production capacity in order to cover these additional fixed costs. Unless demand for the goods these firms produce somehow changes, firms will merge, reducing the number of competitors and reducing the degree of rivalry. Pashigian (1984) found that, all else being constant, industries with higher burdens of environmental regulation also had more rapid growth in mean plant size and more rapid decreases in the number of production facilities in an industry, compared to less regulated firms. To illustrate the role of increased fixed costs on market concentration, consider the following example.

Suppose that a wood table manufacturing firm has an annualized fixed cost of $100,000 (production equipment, facility, owner's time), while, on average, each table is comprised of $50 worth of wood, labor, fasteners, and stain. What is the break-even output level of this firm if market demand is such that tables sell for $300 each? To answer this, note that breaking even occurs when output is such that the average table costs $300 to produce. Currently, each table on average costs $50 in variable costs, so we need to find the output level at which fixed cost on average is $250 per table. This is found by computing the following:

$$\$100{,}000/ x = \$250, x = 100{,}000/250 = 400 \text{ tables.}$$

So the firm breaks even at an output of 400 tables per year, has positive economic profits for output greater than 400 tables, and suffers negative economic profits for output less than 400 tables.

Suppose that there are ten firms each producing 400 tables, so at the market level there are 4,000 tables per year sold at about $300 each. In addition, suppose that each firm must install a collection chamber that increases its annualized fixed cost from $100,000 to $500,000. Assuming that market demand does not change, the new breakeven output level for a firm is:

$$\$500{,}000/ x = \$250, x = 2{,}000 \text{ tables.}$$

Note that the market will only absorb 4,000 tables at a price of $300 per table (and even less at table prices greater than $300), so *at most* the market can only support two firms where it used to support ten firms at the prevailing price. Now these two firms will each be as big as five former firms and will hire many of the workers laid off by those exiting the industry.

The potential problem with a reduced number of firms in this industry is that many economists believe a smaller number of competitor firms are more likely to collude. The argument is that it is much easier for colluding firms to prevent cheating in a group of two firms than in a group of ten firms. Thus, we may see price rise above $300. As the price rises, market quantity demanded falls. So the cartel must choose its price carefully, based on how sensitive consumers are to price increases (factors: number of substitutes, etc.). For example, if the price rises to $400 per table, the break-even output for each firm is:

$$\$500{,}000/ x = \$350, x = 1{,}429 \text{ tables.}$$

As long as market demand is relatively price-inelastic so that quantity demanded is more than twice the single-firm break-even output (more than 2,857), these remaining firms will enjoy positive economic profits rather than just break even. With fewer firms, however, the industry is more susceptible to collusion. Thus, an indirect cost associated with environmental regulation that requires substantial new fixed-cost investments in pollution control is that market concentration rises, competition falls, and firms may be able to exercise more market power, making consumers worse off. Moreover, with less competition there may be less pressure to minimize costs (X-inefficiency), further raising consumer prices.

In closing, recall from chapter 1 that some argue that another indirect cost of environmental regulations is overall job loss, the export of production facilities to "pollution havens," and declines in productivity and competitiveness in international trade. It was shown in the introductory chapter of this book that these arguments have little currency when confronted with empirical research on the job and productivity implications of environmental regulations. In particular, pollution control and clean technologies tend to be labor-intensive, and the exportation of production facilities to low-income countries has primarily been driven by enormous labor cost differences rather than environmental regulations. Finally, there is little evidence that environmental regulations are responsible for more than a small fraction of the decline in productivity growth rates experienced in the United States.

Summary

- Benefit/cost analysis (BCA) is the way in which utilitarian concepts of ethical social policy are operationalized in policy-making. In this context, an environmental or other policy is said to be efficient if it generates the greatest net benefit to society. The Kaldor–Hicks criterion for efficiency judges a policy based on the extent to which aggregate net benefits to society are maximized. The more restrictive Pareto criterion for efficiency requires that any change from the status quo not only generate positive net benefits but also not make any member of society worse off. Thus, the Pareto efficiency criterion is concerned with how benefits and costs are distributed in society, whereas the Kaldor–Hicks criterion is not.
- A requirement of BCA is that benefits and costs be measurable and comparable on a common metric.
- Dynamic efficiency occurs when the policy option is selected that generates the largest PDV of net benefits or, alternatively, that generates the largest PDV of benefits per PDV dollar of cost. It is particularly challenging and important to measure the benefits of proposed regulations for protecting or enhancing aspects of the natural environment that are not marketed. The reason is that in well-functioning competitive

markets, price provides extensive information on the value of the object being traded. In particular, one can estimate a demand curve for the good and estimate consumer surplus, the excess of willingness to pay over and above price.

- Economists have developed a number of techniques for measuring the benefits of environmental protection and enhancement that are not directly traded in markets. These methods include quantitative risk assessment of pollutants affecting human health and various methods for measuring the value of environmental conservation, including the contingent valuation method, the travel cost method, and the hedonic regression method.
- Quantitative risk assessment uses health data to determine the relationship between pollution or workplace hazards and the statistical likelihood of mortality or morbidity in a given-sized population. This information can then be compared to the cost of incremental reductions in various pollutants or workplace hazards, and thus regulatory policies can be made consistent with one another.
- The contingent valuation method is the only one of the three that is capable of measuring passive-use values such as existence and option values. A disadvantage of this method, however, is that data are gathered by way of a hypothetical survey. Nevertheless, studies indicate that well-constructed surveys using the dichotomous-choice referendum format perform remarkably well in parallel studies with actual referenda.
- The travel cost method offers a way of acquiring information on the active-use value that people assign to an area. The data are based on actual expenditures rather than hypothetical surveys, but cannot measure passive uses in which people do not travel to an area.
- The hedonic regression method is also based on actual expenditures and measures the indirect value of individual environmental attributes associated with something that is marketed, such as the value of safety or a scenic view associated with residential real estate.
- The cost of environmental regulation can be divided into direct and indirect costs. Direct compliance costs include pollution abatement and expenditures by firms, consumers, and government, as well as opportunity costs that can be attributed directly to regulation. There are also various different indirect costs that result as feedback effects from environmental regulation, such as higher product prices, reduced output, higher interest rates, reduced economic growth, and more concentrated industries.
- Many factors limit the applicability of BCA in environmental regula-

tory applications. For example, ethical, spiritual, and religious values cannot be reasonably quantified. Benefits are often diffuse and, because they are not traded in markets, do not have prices that reveal value, making them difficult to measure comprehensively. In addition, it may be difficult to attribute environmental improvements to a single action. Moreover, the benefits (or costs) to future generations of people affected by current regulations are discounted as a requirement for dynamic efficiency, but this discounting biases us away from policies with up-front costs and benefits enjoyed by future generations. It is impossible to know for certain what preferences future generations will have regarding the environment. Aggregate benefits and costs may not be equitably distributed, and a dollar will generate substantially more utility for a poor person than for an extremely wealthy person. The impact of environmental regulations is not easy to estimate with certainty, and so risk assessment is often required.

Review Questions and Problems

1. Make up a hypothetical table for the cleanup of some pollutant as in the lecture notes to illustrate the use of the efficiency standard and benefit/cost analysis. Set up your table with:

The first column showing equal 10 percent increments of reduction in the pollutant

The second column showing the *total* (cumulative) cost of cleanup up to that point

The third column showing the *marginal* cost of cleaning up for each 10 percent increment

The fourth column showing the *total* (cumulative) benefit of cleanup

The fifth column showing the *marginal* benefit of cleanup for each 10 percent increment

The sixth column showing the *marginal* net benefit (marginal benefit–marginal cost) for each 10 percent increment

The seventh column showing the *total* (cumulative) net benefit (total benefit–total cost)

a. Construct and carefully label your table.
b. Carefully graph your marginal benefits and marginal costs data.
c. Briefly explain why the trend in marginal benefits and marginal costs in your table makes sense for the pollutant you are using in your example (e.g., why you might have diminishing marginal benefits and increasing marginal costs, or constant marginal benefits and increasing marginal costs).

d. Identify the level of cleanup that yields the maximum possible total net benefit. Briefly describe the conditions that must be true for this level of cleanup to be truly socially optimal. In other words, for what reasons is it true that existing "best methods" may still undermeasure or overmeasure benefits or costs?

2. Do some library research and find a study that uses nonmarket valuation techniques to measure the benefits of some natural resource or environmental amenity. Likely journals include the *Journal of Environmental Economics and Management, Land Economics,* or *Ecological Economics.* Write a one-page review of the study, including the target area of analysis, the methods used, and the research findings.

3. Discuss the advantages and disadvantages of the three methods for measuring the value of environmental amenities in the context of valuing a neighborhood park. Which method, or combination of methods, would you use and why?

4. Access the Internet site for the National Center for Environmental Assessment (http://www.epa.gov/ncea/). Find a risk assessment report for a particular toxic pollutant and summarize the findings.

5. Access the Internet study *Dying Too Soon: How Cost-Effectiveness Analysis Can Save Lives* (http://www.ncpa.org/studies/s204/s204.html) by Professor Tammy Tengs. If the value of a statistical life is approximately $5 million, and if preventing premature death is the only benefit of the regulation, then based on Tengs's cost-effectiveness analysis, what are some examples of regulatory interventions that fail the cost/benefit test? How might your answer change if there are other benefits associated with the regulatory intervention? How might your answer change if the value of a statistical life is considerably lower, such as in a developing country?

Internet Links

Cost-Benefit Analysis and Regulatory Reform: An Assessment of the Science and the Art (http://www.rff.org/disc_papers/abstracts/9719.htm): Resources for the Future *Discussion Paper* 97–19 (1997) by Raymond J. Kopp, Alan J. Krupnick, and Michael Toman.

***Dying Too Soon: How Cost-Effectiveness Analysis Can Save Lives* (http://www.ncpa.org/studies/s204/s204.html)**: Work by Professor Tammy Tengs on the cost-effectiveness of various regulations in which she divides the total cost of a regulatory intervention by the number of statistical life-years saved by the regulation. Site sponsored by the National Center for Policy Analysis (NCPA Policy Report 204).

Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (http://www.wrsc.usace.army.mil/iwr/pdf/p&g.pdf): PDF file that contains the “principles and guidelines” for, among other things, using the travel cost and contingent valuation methods of nonmarket benefits measurement techniques.

EPA’s Economy and Environment Website (http://www.epa.gov/oppe/eaed/eedhmpg.htm): You can access a wide variety of EPA economic studies, including the benefit/cost analysis of the Clean Air Act (CAA) cited in the text.

National Center for Environmental Assessment (http://www.epa.gov/ncea/): A division of the EPA’s Office of Research and Development, the National Center for Environmental Assessment serves as the national resource center for the overall process of human health and ecological risk assessments. This includes the integration of hazard, dose-response, and exposure data and models to produce risk characterizations.

Risk Assessment for Toxic Air Pollutants: A Citizen’s Guide (http://www.epa.gov/oar/oaqps/air_risc/3_90_024.html): A nice description of the risk assessment process for toxic air pollutants that is detailed and easy to understand.

Studies of the Environmental Costs of Electricity (http://www.emanifesto.org/OTAEnvironmentalCost/): An accessible description of the methods and the role of environmental cost studies for electricity, from the Office of Technology Assessment (U.S. Congress).

Survey of Pollution Abatement Costs and Expenditures (http://www.census.gov/econ/www/mu1100.html): This PDF file provides access to the 1994 Pollution Abatement Costs and Expenditures report from the U.S. Census Bureau.

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7

The Political Economy of Environmental Regulation and Resource Management

Introduction: What Is Political Economy?

Theories of political economy distinguish themselves by depicting systematic relationships among economic, social, and political processes. Beyond this very general definition, there are strikingly different schools of thought. Adam Smith, Karl Marx, and John Stuart Mill, for example, were deeply concerned with the interconnectedness of social, economic, and political phenomena. These early political economists, as well as those who have followed in their tradition, approach political economy from widely different normative foundations. For example, the libertarian perspective is that the individual is analytically and normatively fundamental, and as a consequence, social policy, and society itself, serves as an instrumentality for the pursuit of self-interest. In contrast, socialists and other critics of the libertarian position hold that society can shape individual behavior in beneficial ways, and that social policy in turn reflects broad social forces such as classes and interest groups. There is a more recent development, sometimes referred to as the *new political economy*, which adopts a *rational choice framework* drawn from economics. A comprehensive presentation of the full range of thought on political economy is beyond the scope of this chapter. Instead, attention will be focused primarily on the application of new political economy theory to environmental economics, policy, and the collective-choice problems associated with the governance of common-pool resources (CPRs).

In chapter 4 we developed the economic theory of efficiency-enhancing environmental regulation. But because environmental regulation is an outcome of political processes, the nature of environmental regulation will reflect the economic forces at work in the political process. Hence, new political economy models can help us understand how regulation comes about. Rational-choice models of political economy develop a linkage between the institutional structure of the political process, the preferences of decision makers, and the preferences of those affected by regulation. We will see, for example, that the process of developing environmental regulation can be modeled in a supply and demand framework. The supply and demand framework is not the only way to model environmental political economy, and we will consider a number of other approaches, including those addressing the governance of locally self-governed CPRs.

Studying political economy can also help us understand cases of *government failure*, in which policymakers fail to craft environmental policies that adequately resolve market failures at reasonable cost. Therefore, while market failures provide a theoretical or conceptual justification for regulatory intervention, one must also critically evaluate the efficiency of the regulatory intervention itself. Such a critical evaluation can help us understand why existing regulatory schemes do not function as expected and can thus be a first step in the design of more effective regulatory incentives and institutions.

In this chapter, we will first develop a political–economic model of the regulatory process that uses supply-and-demand methodology. Next, we will describe some of the more important models of political economy that have been developed by economists studying the regulatory process. We will then discuss how these models have been applied to the political economy of environmental regulation, to the governance of CPR systems, and to the process of forming international environmental accords.

Economic Models of Political Economy and the Regulatory Process

Introduction

Economists who study the political process are interested in explaining government policies as a function of (1) optimizing *rational choice* behavior by the policymakers (behavior consistent with optimizing over some set of objectives), (2) modified by incentives from various sources, and subject to (3) political and other institutions (the rules of the game). Peter Ordeshook (1990) has argued that the extension of this *rational choice paradigm* to politics, which is the foundation of thought in political economy today, represents a case of *imperialism* (expansion of territory using power) by microeconomic theorists such as Arrow (1951) and Olson (1965).

Political economy models can be used to help explain and predict policy outcomes. For example, consider the choice between a state's gathering revenues through a sales tax or an income tax. Sales taxes tend to be more *regressive*, meaning that they take a larger percentage of the income of poor people relative to rich people. The reason for this is that poor people spend a much larger share of their income on items subject to sales tax than do rich people, who save and invest a substantial portion of their income. In contrast, income taxes are usually graduated and take a larger share of the income of rich people, making them *progressive.* Thus, income taxes will tend to be the preferred method of taxation for candidates who position themselves to represent the interests of low-income people, while sales taxes will tend to be the preferred method of taxation for candidates who represent upper-middle-class and wealthy people. Hence, in those states where the very poor have a very low voter participation rate, and so represent a minority of voters, one could predict that the tax structure will tend to make greater use of sales taxes relative to income taxes.

Early work in the rational-choice approach to political economy by Buchanan and Tullock (1962) led to the creation of the branch of political economy known as the *public choice* school of thought. Instead of assuming that politicians select policies that best serve the public interest, traditional public choice models start from the premise that politicians, like other economic agents, are motivated by incentives such as ideology, wealth, reelection, and power. From this foundation one can model the supply of legislation or administrative rules. For example, Kalt and Zupan (1984) found that the voting behavior of legislators can be explained as a function of both individual ideology and the requirement to satisfy the economic and other interests of the constituents whose votes are needed to remain in office. While factors such as ideology, reelection, and the like help us understand the supply of regulation, legislative and administrative outcomes also depend on the institutional structure within which these activities occur. Shepsle and Weingast (1994) offer an accessible survey of the work that has been done on the institutional structure of the U.S. Congress. For example, issues such as party control, seniority, the role of committees and committee chairs, voting rules, and other aspects of procedure are important elements in understanding legislative outcomes. A different institutional structure governs the administrative rule-making process.

While some economists and political scientists were studying the behavior of legislators and others on the supply side of regulation, a number of economists associated with the Chicago school of economics were developing a political economic model of the demand for regulation. Stigler (1971) argued that firms will lobby legislators for regulation when such regulation provides (1) direct monetary subsidies, (2) constraints on substitute products or subsidies on complementary products, (3) easier price-fixing/collusive atmosphere, and (4) incumbent firms with the ability to control entry by potential new rivals. Together with the work of Peltzman (1976), Stigler is credited with the development of the *capture theory of regulation*. In this model, firms (or others) "capture" the regulatory process because each firm potentially bears a high cost if regulation constrains its behavior, so each firm has a lot at stake. In contrast, while the public as a whole also has a lot at stake, any one person generally has only a very small stake in the regulatory process, and so has little incentive to invest resources in affecting the regulatory process. At the same time, there are comparatively few firms relative to the overall public, so the cost of organizing the firms is low compared to the cost of organizing the public. As a result, firms have both the incentive and the better opportunity to invest resources successfully in lobbying for favorable regulation. As with the later work of Becker (1983), the capture theory of regulation ignores the supply side of the regulatory process, and it assumes that regulation is an outcome of interest group competition.

There is evidence consistent with the capture theory of regulation. One example is *revolving-door* deals, in which high-level regulators and other officials leave government and find high-level jobs in the same industry that they had been responsible for regulating. Although it is difficult to prove a causal relationship between regulatory decisions and future employment, careful attention to the interests of regulated industries can be a highly lucrative career-building strategy for senior government regulators. Sanjour (1992) provides a remarkable accounting of the possible revolving-door relationship between the EPA and the hazardous waste industry. For example, Sanjour reports that the chief EPA administrator, William Ruckelshaus, became a director of Weyerhauser, Monsanto, and CEO of Browning Ferris, all regulated by the EPA. Douglas Costle, another chief EPA administrator, reportedly became chairman of Metalf and Eddy, a superfund contractor. Another EPA administrator, Lee Thomas, reportedly became CEO of Law Environmental, a hazardous waste firm. Similarly, various deputy administrators, acting administrators, assistant administrators, and regional administrators, as well as enforcement attorneys, reportedly gained high-level employment in hazardous waste firms such as Waste Management, Chemical Waste Management, Browning Ferris, and Rollins Environmental Services. Likewise, Greenberg (1993) found that 80 percent of top EPA officials who had worked with toxic waste cleanups and who left government between 1980 and the time of his study, joined firms holding Superfund cleanup contracts, consulted with, or gave legal advice to companies about dealing with Superfund. More generally, Lewis (1998) found that between 36 and 40 percent of senior staffers serving members of key congressional budgetary committees left to become registered lobbyists between 1991 and 1996. In a July 1999 news release, the group Common Cause reported that 128 former members of Congress were lobbyists in 1998, and that at least 22 percent of lawmakers leaving office became lobbyists in the 1990s, compared to only 3 percent in the 1970s.

Additional support for the capture theory of regulation comes from a 1997 *Los Angeles Times* analysis of political contributions by major U.S. corporations. That report found that the largest contributors tended to be those most heavily regulated by government or most dependent upon government for subsidies (Vartabedian 1997). Clearly, these companies have a high demand for favorable regulation. By the same token, firms with a reputation for sound management, and which therefore have a relatively lower demand for favorable regulation, were found to be below-average contributors. From a sectoral point of view, the largest political contributors reportedly came from the financial, military, oil, telecommunications, and tobacco industries.

The Political Market for Regulation

In this section, we will see how the two strands of the rational-choice theory of political economy described in the preceding section can be brought together in a simple equilibrium supply and demand framework. Because regulation may have its origins in both legislation and in administrative rules, we will use the term "regulator" to refer to the agent (either legislator or administrator) who participates in the production of regulation. We will assume a competitive market in which the equilibrium level of effective support for a particular regulation is the outcome of interaction between interest groups and regulators. This section of the chapter is loosely based on the work of Keohane et al. (1999).

The demand for regulation derives from the various groups whose interests are served by regulation. Because regulation is a public good, and because political influence is costly, individuals are unlikely to find it worthwhile to participate on their own. Interest groups are effective because they pool the resources of many individuals and reduce the total cost of lobbying activity. However, because regulation is a public good, interest groups suffer from free-riding problems (Olson 1965). Effective interest groups are able to overcome the free-rider problem by offering membership benefits such as solidarity, access to regulators, and information. Interest groups organize around a common set of preferences, and they therefore express a group willingness-to-pay (WTP) for effective support of a regulation that reflects the marginal utility derived from the regulatory outcome. This WTP is manifested as political currency that includes money payments, votes, volunteer effort, and endorsements. Stigler and Peltzman's capture theory of regulation suggests that interest groups are most likely to be successful in influencing regulatory outcomes when individual members have a large WTP for favorable regulation, and when the interest group is able to effectively organize and focus its collective preferences.

Those who study the demand for regulation characterize several specific types of interest groups. Firms often organize themselves in trade associations. As Stigler and Peltzman observed, these trade associations are likely to seek regulations that reduce their production costs, that provide subsidies, that erect entry barriers and constrain substitutes, and that provide an environment more conducive for collusion. Environmentalists organize themselves into groups that lobby for regulation that conserves or restores the environment. Likewise, consumers may organize themselves into interest groups seeking lower product prices and product quality assurance, and workers may organize into interest groups seeking more jobs, higher pay, and better working conditions.

As Keohane et al. (1999) argue, the supply of regulation has three components, each reflecting the cost of supplying effective support for a particular regulatory outcome. First, the supply of regulation is a function of the opportunity cost of the time and effort invested by the regulator in shepherding environmental legislation or administrative rules through the political process. Second, the supply of regulation is a function of the psychological cost of supporting regulation that may be in opposition to the personal preferences of the regulator. It is possible that this cost becomes negative if the regulation is in accord with the regulator's personal preferences. Third, the supply of regulation is a function of the opportunity cost of supporting regulation that can impair the regulator's probability of reelection or reappointment. As with the regulator's personal preferences, this opportunity cost can become negative if the regulation is in accord with the interests of the regulator's constituency and thus increases the likelihood of reelection or reappointment. Each of these three components of the supply of regulation affects the utility of the regulator.

The equilibrium concept as it applies to a supply-and-demand model is described in chapter 3. In this more complex political market the price of a unit of effective support, denominated in political currency, reflects the marginal WTP for the groups whose interests are reflected in the demand curve. The equilibrium quantity of effective support is found where the demand for regulation intersects the supply of regulation, as shown in Figure 7.1. What factors might displace this equilibrium and cause an increase or a decrease in the equilibrium level of effective support for a particular regulation? An increase in demand might occur, for example, if a new interest group joins the coalition demanding the regulation. All else being equal, an increase in demand would cause an increase in the equilibrium level of effective support. Likewise, if polls indicate that constituents more strongly favor the regulation, this would increase the supply of regulation and therefore increase the equilibrium quantity of effective support. Each regulatory alternative will have its own supply and demand, and thus will have its own equilibrium level of effective support. Different regulatory alternatives will derive their demand from a different mix of interest groups, and will derive their supply from different regulator opportunity costs.

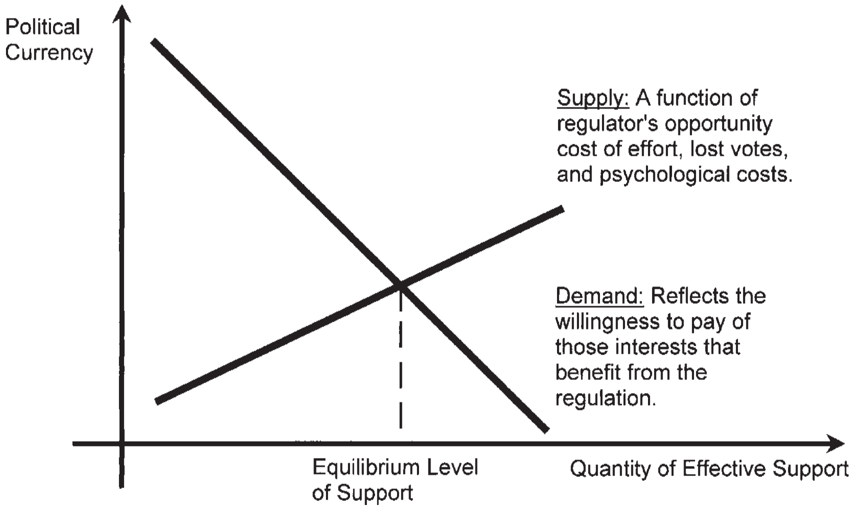
But how do these equilibrium levels of effective support relate to regulatory outcomes? That is the role of political institutions. For example, the rules of governance may require a threshold level of equilibrium support in a legislature in order for a particular regulation to become law. In the case of administrative rule-making, the process may involve selecting from among regulatory alternatives based on which receives the largest level of equilibrium support.

The Political Economy of Environmental Regulation: A Selective Survey

In this section of the chapter, we will review a number of studies that have used the tools of political economy to evaluate environmental regulation. One issue has to do with determining the political economy of how pollution-control laws are implemented by the EPA and other relevant administrative agencies. Implementation involves diverse elements of government, including enforcement policy, field monitoring, sanctioning decisions, and legal activity. Downing (1981) has studied the political economy of the process of implementing pollution-control laws, and his model includes three groups: the polluter, those bearing the pollution costs, and the regulatory agency. The first two groups invest resources to influence the regulatory agency. Downing assumes that the manager(s) of the regulatory agency have the twin objectives of maximizing agency budget and discretionary control, and of improving environmental quality. Polluters, and those suffering from pollution, invest resources in influencing the politicians who set the agency budget, and thus indirectly control the level of pollution-control activity.

This is a useful structure for analyzing the role of interest groups in deter-

Figure 7.1 **The Political Market for Regulation**



mining the nature of particular environmental policies. For example, this model indicates that there is a feedback effect between the type of environmental regulation we observe (e.g., effluent fees, technology forcing) and the pattern of lobbying pressure exerted by the regulated firms. Milliman and Prince (1989) studied a polluting firm's incentives for spending money on research and development (R&D) to find innovative and less expensive ways of meeting the requirements of pollution-control laws. One relationship they studied was the way that firms that succeeded in finding an innovative and lower-cost means of complying with pollution-control laws might influence the introduction of even more stringent environmental regulations. They argue that "firms, not regulatory agencies, often initiate [environmentally friendly] innovation and diffusion" (p. 248).

What sort of influence might such a firm with a cost-reducing innovation exert on policymakers? Hackett (1995) investigated the question of whether polluting firms would ever have an incentive to lobby policymakers for more restrictive regulation of their own industry and used a Stigler-style model of regulatory influence. This counterintuitive scenario can actually occur when doing so would raise the cost of rival firms more than the firm's own cost, as argued by Salop et al. (1984). In Hackett's model, firms are engaged in a patent race to develop less-expensive methods of clean production technology. The incentive to engage in this patent race need not be some external threat from the government. Instead, the winner(s) of the patent race have found a much cheaper method of clean production than the other industry members, and so have an incentive to lobby government for pollution-control regulations. Such regulations raise their costs as well, but they raise production costs of noninnovating rivals even more. As a result, the innovating firms have a cost advantage in the regulated setting, which increases their profits.

The viewpoint offered above is that there are circumstances in which polluting firms actually have an incentive to invest money in pollution-control R&D and, if successful, to lobby for more restrictive environmental laws. There are other somewhat less benign reasons why firms might engage in voluntary pollution abatement. In particular, Maxwell, Lyon, and Hackett (2000) examined the situation in which polluting firms face the possibility of more restrictive environmental laws in the future. They used a demand-side political economy model in which rival interest groups compete with one another to influence policymakers, as in Becker (1983). They found that if the cost of organizing those who suffer from pollution in order to lobby for more restrictive environmental laws is sufficiently high, the polluting firms may have an incentive to engage voluntarily in cleanup activities. But how much voluntary overcompliance will firms select? The answer is just enough to keep those suffering from pollution from organizing, but less than what the firms think they would be forced to clean up if they had to compete in the influence process. As a consequence, firms are able to foreclose the influence process through some voluntary pollution control.

Maxwell and colleagues (2000) used data on the Toxics Release Inventory (TRI) to evaluate whether declines in the cost of organizing political resistance to pollution emissions lead to a greater threat of increased government regulation, driving firms to self-regulate and reduce emissions. The TRI requires firms to self-report their emissions of certain toxic compounds, and thus works to lower the information cost to citizen groups that lobby government for stricter regulations. Ever since the TRI was instituted in 1989, toxic emissions per unit of manufacturing output have steadily declined, which is consistent with Maxwell et al.'s prediction. Moreover, states such as California, which have a very high density of self-identified environmentalists, are shown to have a more rapid reduction in toxic emissions per unit of manufacturing output than states with a lower density of environmentalists. Thus, by simply providing information on pollution emissions, the TRI makes it easier for citizens to threaten polluters with more stringent regulation, which in turn works to lower emissions by way of voluntary self- regulation so as to attenuate the threat of more stringent regulation.

We will now look at applications of political economy that have been used to explain successes and failures in CPR governance.

The Political Economy of Locally Self-Governed Common-Pool Resources

We have discussed a number of different ways that the techniques of political economy have been used to help explain environmental laws and their implementation. The techniques of political economy can also be applied to appropriator groups that form self-governing organizations for managing CPR systems. One of the clearest applications of this methodology is in understanding how appropriator groups solve the problem of internally allocating harvest rights when overall harvest must be reduced in order to protect the productive capacity of the CPR.

Buchanan and Tullock (1962) have argued that the percentage of voters needed for a voting organization (e.g., a legislature, a condominium owners association, or a group of groundwater pumpers) to reach agreement has important cost implications. Building on this notion, Hackett (1992) studied voting rules in CPR systems in which the appropriators differ in one or more important ways. For example, from prior use, some groundwater pumpers may have drawn very large volumes of water from the aquifer, while others may have appropriated only very small volumes. Suppose that the CPR system has been abused from overuse, and the appropriators have just self-organized to reduce overall appropriation levels in order to manage the CPR more sustainably. The question is how the overall reduction in use will be divided among the individual appropriators.

Rule systems that change the original status quo shares redistribute wealth from one type of appropriator to another, and are therefore more likely to generate conflict. For instance, suppose that a groundwater basin is found to be in overdraft and new rules are developed to reduce the daily quantity of water to be withdrawn from the aquifer. Wealth will be redistributed from historically small appropriators to historically large appropriators if all appropriators must cut back by the same number of gallons per day. Wealth will be redistributed from large appropriators to small ones if groundwater quota shares of equal size are assigned without regard to historical pumping levels. In contrast, a rule system that requires all appropriators cut back by the same percentage from historical use levels is neutral and does not redistribute wealth. Self-governed CPR appropriators must resolve this distributional conflict in order to achieve more sustainable use of the CPR.

The larger the percentage of voters required to reach agreement on a distributional rule, the more inclusive the voting rule. The extreme case would be a consensus rule. Hackett (1992) developed a model that identifies the following trade-off: heterogeneous groups with highly inclusive voting rules will take a longer time to reach agreement because such voting rules make it easier to block agreements. This delay allows the CPR to continue to decline in productivity. Distributional rules that are approved, however, are less likely to result in large redistributions of wealth relative to the status quo, and so individual appropriators are less likely to fight and violate such rules, reducing future monitoring and enforcement costs. In contrast, less inclusive voting rules, such as a simple majority rule, are more likely to result in a redistribution of wealth from the minority to the majority of voters, and so repair of the CPR system is not delayed. Yet if the majority does manage to pass highly redistributive rules, the agreement is more likely to be fought and violated by the minority in the future, resulting in higher monitoring and enforcement costs.

Thus, self-governed yet highly heterogeneous CPR appropriator groups may have to trade delay costs with higher monitoring and enforcement costs when they devise their voting rule. Hackett, Schlager, and Walker (1994) used laboratory experimental techniques to look at how groups resolve this problem. Laboratory experiments such as these have people role-play the interactions of CPR appropriator groups. The incentive to take this seriously is created by using cash payments to re-create the incentives that are present in naturally occurring CPR systems. The advantage of laboratory techniques is that they allow researchers to test the hypotheses of models for which data are not available from naturally occurring sources. Hackett and colleagues created heterogeneity in appropriator size—large appropriators had the capability (and the history) of harvesting a much larger volume from the CPR than did the small appropriators. After allowing appropriators to abuse the CPR, they were given the opportunity to communicate freely and devise a sharing rule to (1) reduce overall harvest on the CPR and (2) allocate these reduced harvest rights among the appropriators themselves. Hackett et al. (1994) found that this form of heterogeneity did not seriously deter appropriators from forming successful sharing rules. When large appropriators had to pay for their added harvest capacity, sharing rules allocated larger harvest shares to them relative to those with smaller harvest capacity. These proportionate sharing rules were seen as being fair and prevented the large-capacity appropriators from cheating on the agreement.

There have been a number of field studies as well. For example, the effects of appropriator heterogeneity and voting rules on the performance of CPR governance structures have been looked at for the case of oil and gas fields by Wiggins and Libecap (1985) and Libecap and Wiggins (1985). As Wiggins and Libecap (1985) point out, "[c]onflict over estimated lease values and unit shares [sharing rules] is the heart of the contracting problem" (p. 372). Self-governance on oil and gas fields with many individual mineral rights holders is important, because excessively rapid competitive "pumping races" deplete the natural pressurization in the oil pocket that allows the oil to be brought to the surface. They found, for example, that self-governance was far more successful in the state of Wyoming, where oil fields are primarily on federal land, and federal policy encourages agreements prior to pumping when heterogeneities could set in. By 1975, 82 percent of Wyoming oil came from fields with sharing-rule agreements and controls on overpumping. Agreements were far less common in Texas, where pumping could occur prior to talks on self-governance, allowing heterogeneities to set in. Moreover, unanimity is required for agreement in Texas. As a result, while major oil fields were developed in Texas in the late 1920s and early 1930s, only 20 percent of the state's overall oil production came from self-governed pumpers by 1975. Oklahoma, in contrast to Texas, allowed for legally binding sharing-rule agreements when at least 63 percent of the pumpers (weighted by acreage of mineral rights) agreed to a sharing rule. By 1975, nearly 40 percent of Oklahoma oil came from fields with sharing-rule agreements and controls on overpumping. Thus, heterogeneity and highly inclusive voting rules both contribute to delay in forming effective CPR governance structures.

Libecap and Wiggins (1985) also investigated the political economic effects of large- and small-firm oil field appropriator groups in the form of state and federal oil field quota rules. They found evidence that state and federal resource allocation rules vary as a function of the political influence of these two appropriator groups. In Texas, small lease owners were numerous and influential, and they successfully delayed productivity-enhancing oil field CPR rules that favored large lease owners. Conversely, the federal government is both a large lease owner and a supplier of rules for oil fields on public lands, so selected rules favored large lease owners.

Johnson and Libecap (1982) provide a similar analysis of CPR governance structures designed to resolve overuse and to allocate harvest rights. They studied the Texas shrimp industry, where fishers "vary principally with regard to fishing skill" (p. 1005). There is also a biological interdependence between inshore and offshore fisheries, where the productivity of the offshore fishery depends in part on the number of shrimp that migrate there from shallow inshore waters. While fishers' unions and trade associations developed along the U.S. coast to limit entry in order to control overfishing, a series of Supreme Court decisions during the 1940s interpreted these agreements as illegal cartels, like the Organization of Petroleum Exporting Countries (OPEC), and the agreements were subsequently dismantled. Johnson and Libecap point out that heterogeneity in skill created conflict over the type of government fishery regulations the various fishers preferred: "For example, total effort [in catching fish] could be restricted through uniform quotas for eligible fishermen. But if fishermen are heterogeneous, uniform quotas will be costly to assign and enforce because of opposition from more productive fishermen" (p. 1010).

Field research generally indicates that rules linking CPR output shares to an appropriator's size and historical level of CPR harvest (number of fishing boats, acres under irrigation) or contribution (effort or financial contributions for upkeep or monitoring and enforcement) are far more common than rules that simply divide CPR output equally. There is an aspect of fairness in rewarding greater contributions with larger shares, and sharing rules that differ markedly from historical use patterns tend to undermine individual cooperation with group efforts directed at improving the conditions of the commons.

Thus, we have seen that the techniques of political economy and public choice are helpful in understanding the problems and challenges associated with successful self-governance of localized CPRs, as well as the nature of the rule structures these groups develop. Heterogeneity and highly inclusive voting rules for reaching agreements explain a substantial amount of the delays, high costs, and failures of CPR governance. These problems occur because incompatible incentives of individuals create distributional conflict, and highly inclusive voting rules increase the strategic power of individual appropriators to hold up agreements for special treatment.

The Political Economy of International Environmental Accords: The Case of the Montreal Protocol

The methods of political economy can also be used to help us understand the nature of international environmental accords. One of the most prominent of these is the Montreal Protocol, which sets an international schedule for the banning of chlorofluorocarbons (CFCs) and related chemicals that deplete atmospheric ozone. Oye and Maxwell (1995) offer a comprehensive political economic analysis of the Montreal Protocol, and we will draw heavily upon their work in this case study.

Oye and Maxwell argue that successful environmental management occurs when narrow, self-interested behavior is also consistent with the common good, and thus those interested in the common good should look for opportunities to foster these linkages. This is something like Adam Smith's notion that the *invisible hand* of the marketplace transforms narrowly self-interested behavior into efficient outcomes. In particular, their case study analysis of the Montreal Protocol and other environmental agreements indicates that environmental regulations work most effectively when they create benefits for those firms being regulated.

Theoretical Foundation

Consider two different regulatory situations. One of these we shall refer to as *Olsonian* cases, using the terminology developed by Oye and Maxwell for regulatory situations matching those described in the work by Olson (1965) on privileged groups. In Olsonian situations, regulatory benefits are diffuse, spread thinly across many entities, while regulatory costs are concentrated, weighing heavily on a few entities. In Olsonian situations, the many who receive relatively small benefits from regulation have little incentive to invest in activities to influence policy; moreover, as Stigler argued, they also face high organizational and coordination costs because of their large numbers. Conversely, the few who bear a particularly heavy regulatory burden (e.g., large polluting firms) have an incentive to organize opposition, and by being small in number they also face smaller organizational costs. Thus, in Olsonian situations it is more difficult to get *stable systems of regulation*, meaning that regulatory controls for protecting the environment, for example, are relatively likely to be overturned owing to the lobbying efforts of the few who bear the costs.

In contrast to Olsonian regulatory situations are *Stiglerian* cases, named after Nobel Prize–winning economist and regulatory scholar George Stigler. Recall that in Stiglerian situations the benefits of regulatory controls are concentrated heavily on a few entities, while the costs are rather thinly spread across many entities. Regulatory controls are more *stable* in Stiglerian situations because the influence advantage falls to those who benefit from the regulation, whereas those who would like to overturn the regulation have relatively little incentive to do so and also face high organizational costs.

Oye and Maxwell argue that the Montreal Protocol case features conditions (2) and (4) (constraints on substitute products or subsidies on complementary products; ability of incumbent firm to control entry by potential new rivals) because the protocol, which outlawed CFC production by the year 2000, gave a particularly strong advantage to firms like Du Pont, which came up with CFC alternatives, over rivals that did not. In particular, Oye and Maxwell (1995) find that the “Du Pont and Imperial Chemical Industries, Ltd. (ICI) experience with restrictions on CFCs represents a classic Stiglerian illustration of producers benefiting from regulations mandating product substitution” (pp. 193–94). The material below closely follows that of Oye and Maxwell.

Case Study: The International Political Economy of CFC Control

Halocarbons, two prominent forms of which are CFCs and halons, are substances that combine chlorine, fluorine, iodine, and bromine. The CFCs were invented in the 1930s, and up to the 1970s they were considered one of the most successful products of the chemical industry. In particular, CFCs are stable, easy to produce, and have wide application in refrigeration, as aerosol propellants, and in industrial cleaning and manufacturing uses. In an important study published in 1974 in the journal *Nature*, however, scientists Molina and Rowland argued that CFCs could, despite their heaviness, reach the upper atmosphere through surface turbulence, at which time ultraviolet (UV) radiation would cause the CFCs to decompose into free chlorine, each molecule of which is capable of consuming large quantities of stratospheric ozone. Moreover, CFCs can persist in the atmosphere for 100 or more years. In 1976, the U.S. National Academy of Sciences (NAS) called for elimination of all nonessential uses of CFCs.

In contrast, the British Department of the Environment was much more cautious, calling for further research before any regulatory actions. In the face of state-level bans and rising consumer concerns motivated by environmental activism in the United States, firms such as Johnson Wax announced in 1975 that they would voluntarily phase out CFCs in aerosol applications. Other U.S. consumer products companies followed. In 1978, the United States—along with Canada, Denmark, Norway, and Sweden—banned the use of CFCs as aerosol propellants. Interestingly, in Great Britain, 80 percent of CFC use, in the late 1970s was in aerosol applications, while in the United States air conditioning made up approximately 50 percent of CFC use. ICI, at the time Britain's largest single manufacturing firm and a major producer of CFCs, would thus have been disproportionately harmed by an aerosol ban, which Britain opposed.

In 1979, the NAS estimated that a 16 percent reduction in the ozone layer would result in several thousand more cases of skin cancer each year, both fatal and nonfatal, and the reduction in ozone would also harm crop yields. Following this, the Carter administration's EPA sought to reduce U.S. production of CFCs further, and pressed European countries to also ban aerosol and other nonessential applications of CFCs. Only token regulation followed. Thus, weak European regulation together with the U.S. ban on aerosol applications led to less U.S. production and, in fact, to a manufacturing overcapacity in the United States, whereas in Britain expensive new production facilities were being added to accommodate its increased share of worldwide CFC production.

By the early 1980s, the new Reagan administration was opposed to further CFC controls. Moreover, the new scientific evidence coming in during the early 1980s supported the more cautious British perspective on CFCs; for example, the NAS adjusted downward its estimate of ozone layer reductions from 16 percent to 2–4 percent in 1984. Low-level international negotiations commenced, culminating in the Vienna Convention, which called for the international community to eventually control ozone-depleting chemicals, but lacked specific measures. The research programs begun in the mid-1970s for CFC alternatives by Du Pont and ICI were discontinued in the early 1980s *because of a lack of a market for CFC alternatives at the time.*

This rather rosy picture of CFCs and ozone depletion was smashed by Farman, Gardiner, and Shanklin's 1985 study, also published in *Nature*, reporting for the first time the total destruction of the ozone layer in the antarctic polar vortex. This information was widely reported, and public awareness was high; like Rachel Carson's book *Silent Spring*, it resulted in a translation of public concern into policy. The U.S. position in reopened international negotiations was that CFCs should be totally phased out by 1995. Importantly, Du Pont adopted the position in 1986 that international regulations should limit worldwide production to then-existing *levels*. Thus, Du Pont revealed a willingness to shift its capacity to the manufacture of CFC alternatives. In contrast, the British government argued for a cap at existing *production capacities*. The British were quite concerned about protecting ICI, which had recently invested in profitable new CFC production facilities, while in the United States, Du Pont and other CFC makers were continuing to experience excess capacity in older facilities, low profit margins, and the very real possibility of an outright domestic production ban.

Thus, Du Pont wanted an *international restriction* so that ICI would be disproportionately harmed. The CFC alternatives market promised profit-making opportunities for Du Pont, which had developed CFC alternatives. Production of these alternatives would require substantial fixed-cost (capital) investment in precision manufacturing facilities, which would eliminate smaller producers and thus likely feature higher profit margins for Du Pont. The new chemicals were projected in the mid-1980s to sell for between five and ten times the price of CFC-11 and CFC-12, so major users (e.g., the automotive and appliance industries) would not voluntarily switch without government regulation.

Note the Stiglerian nature of the situation. Financial benefits were concentrated on Du Pont, while the costs were spread across many manufacturers. Yet since the increased cost of the CFC alternatives was still only a small fraction of overall manufacturing cost, their cost burden was relatively small. These costs could be further mitigated by a phase-in period to allow manufacturers time to adjust compressors and other technologies to the CFC alternatives. This transition would require a public/private coordination that Du Pont was eager to provide. Hence, Du Pont saw that it needed to promote this regulation to create a profitable new market for itself, which would benefit Du Pont more than ICI.

The *Montreal Protocol on Substances That Deplete the Ozone Layer*, agreed to under the auspices of the United Nations, was signed by representatives of 24 countries in 1987. The Montreal Protocol called for the 24 signatory countries to reduce CFCs and halons by 50 percent relative to 1996 levels. Two weeks after the signing of the Montreal Protocol, new evidence was presented by the National Aeronautics and Space Administration (NASA)/World Meteorological Organization (WMO) Ozone Trends Panel, which revealed that substantially more ozone depletion was occurring over mid- and high-northern latitudes during winter than had been anticipated by earlier science. Within ten days of the NASA/WMO study's release, Du Pont announced plans to eliminate CFC production voluntarily and to speed transition to CFC alternatives. ICI later followed Du Pont's lead. At a European Community meeting in March 1989, British officials, attempting to look good by proposing an 85 percent reduction in CFCs by 1999, were upstaged by representatives from other European countries, who forced an agreement for signatory countries to phase out production of CFCs completely by 2000. The agreement became known as the London Revisions to the Montreal Protocol, signed in June 1990. The London Revisions called for high-CFC-consuming signatory countries to end CFC production and consumption by 2000. Some countries have unilaterally used an accelerated phaseout schedule; for example, the United States committed to a complete phaseout by the end of 1995. The London Revisions also included a phaseout of carbon tetrachloride by 2005 and established a schedule for phasing out halogenated CFCs (HCFCs).

Though developing countries argued that 80 percent of CFC consumption was by developed countries, it was clear that the Montreal Protocol would be jeopardized if developing countries refused to ratify it. Accordingly, the London Revisions gave low-CFC-consuming countries a ten-year grace period on the phaseout of CFCs. As Alberty and VanDeveer (1996) have observed, these exemptions were required to get key developing countries to support the agreement. Moreover, Alberty and VanDeveer go on to report that India and China later refused to ratify the Montreal Protocol unless an additional side agreement was reached in which rich countries would provide a fund to be used to subsidize the costs of installing technologies for utilizing CFC alternatives in poor countries. As a consequence, the London Amendments created this multilateral fund, and estimates at the time were that approximately $2 billion would be required. Alberty and VanDeveer report that, while rich signatory countries originally pledged $240 million if India and China were to sign, actual contributions are far below the pledges. Nevertheless, these side payments from rich countries to poor countries have become a model for international environmental agreements, such as those attempted for climate change and biodiversity.

The CFCs produced in developing countries like China and India and smuggled into developed countries where their production was banned became a problem in the early years of the phaseout, but more recent estimates indicate that much of the smuggling has been curtailed. For example, In December 1995, *The Economist* reported that CFC production in developing nations increased 87 percent following the phaseout, and exports by 1,700 percent, between 1986 and 1993. The EPA (USEPA 1999) estimates that between 7.5 million and 15 million pounds of Freon (CFC-12 or R-12) was smuggled into the United States each year between 1994 and 1995. *The Economist* estimated that 20 percent of all CFCs in use in 1995 had been bought on the black market. Since then, the U.S. government has clamped down on smuggling. The EPA (USEPA 1999) estimates that between 5 million and 10 million pounds of Freon were smuggled into the United States each year between 1996 and 1997. By mid-1997, 2 million pounds of Freon had been impounded by U.S. Customs, and by the end of February 1999, over 90 individuals and businesses had been charged for smuggling Freon into the country. The remaining stockpile of Freon in the United States was estimated to be between 24 million and 48 million pounds at the beginning of 1999. As the price of the dwindling stocks of Freon continues to rise, the cost of converting to Freon substitutes will become increasingly attractive.

As we have seen, international regulations mandating a CFC ban offered firms like Du Pont the Stiglerian solution of new and more profitable markets, which, because of higher fixed costs, would be more concentrated and thus less competitive than the former CFC marketplace. The financial cost of adjusting to CFC alternatives was diffuse across the many consumer products companies and was still only a small part of overall manufacturing costs, weakening the companies' incentive to organize resistance.

Summary

- Political economy is a method of analyzing the incentives, institutions, and outcomes of governance problems.
- Environmental laws and policies are outcomes of political processes, and so political economy can be used to explain why particular laws and policies occur. The techniques of political economy are also useful in helping us understand cases of "government failure" to craft environmental policies that adequately resolve market failures at reasonable cost. Such a critical evaluation can help us understand why existing regulatory schemes do not function as expected and can thus be a first step in the design of more effective regulatory incentives and institutions.

- Economists who study the political process are interested in explaining government policies as a function of (1) optimizing *rational choice* behavior by the policymakers (behavior consistent with optimizing over some set of objectives) and (2) behavior modified by incentives, subject to (3) political and other institutions (the rules of the game).
- Stigler (1971) is credited with the development of the *capture theory of regulation*. In this model, firms (or others) capture the regulatory process because each firm potentially bears a high cost if regulation constrains its behavior, so each firm has a lot at stake. In contrast, while the public as a whole has a lot at stake, generally any one person has only a very small stake in the regulatory process and so has little incentive to invest resources in influencing the regulatory process. At the same time, there are comparatively few firms relative to the overall public, so the cost of organizing the firms is low compared to the cost of organizing the public. As a result, firms have both the incentive and the better opportunity to invest resources in lobbying for favorable regulation.
- There is evidence consistent with the capture theory of regulation—for example, the infamous *revolving-door* deals, in which high-level regulators (EPA administrators, for instance) leave government and find high-level jobs in the same industry that they had been responsible for regulating.
- Economists have modeled the regulatory process using the tools of political economy by developing a supply-and-demand framework. The supply of regulation reflects the opportunity cost of effort in developing and shepherding regulation, the psychological cost of supporting regulation that may be inconsistent with the regulator's preferences, and the impacts on the likelihood of reelection. The demand for regulation reflects the willingness-to-pay of groups that aggregate the interests of those who receive a benefit from regulation. The equilibrium level of effective support for a particular regulation occurs where the supply and the demand for regulation intersect.
- While firms generally have an incentive to lobby for less environmental regulation, situations exist in which firms might actually lobby for more regulation. A firm may lobby for regulation when the regulation would raise its rivals' costs more than its own. Firms may also engage in voluntary cleanup when doing so gives those suffering from pollution just enough relief to keep them from organizing to lobby for even more restrictive regulations.
- Political economy models can also be used to explain the sharing rules and voting rules used by self-governing CPR appropriator groups. Heterogeneity in appropriator characteristics and the requirement that nearly

all appropriators agree before rules are implemented are two of the leading causes of rule failure in oil, gas, and fishery CPR systems.

- The balance of pressure from various interest groups can also be used to explain the nature of international environmental accords. Oye and Maxwell (1995) show that the Montreal Protocol agreement on control of chlorofluorocarbons (CFCs) was driven by scientific information and pressure by Du Pont to phase out CFCs. Du Pont's pro-phaseout position is consistent with Hackett's model, since Du Pont had developed CFC alternatives and saw an opportunity to dominate in the CFC alternatives market.

Review Questions and Problems

1. Consider the supply-and-demand model of the political market for regulation described in the chapter. How would the equilibrium level of effective support change if industry groups opposing regulation conducted a successful advertising campaign that cast doubt among the public regarding the factual basis for the environmental problems addressed by the regulation? Be specific about shifts in demand and supply.

2. Suppose that "gunk" is a pollution by-product of manufacturing computer processors. Environmental activists propose regulation to limit emissions of gunk. The proposed regulation leads to pollution-control costs that are heavily concentrated upon the small number of companies that produce computer processors. Control costs under the proposal are estimated to be approximately $100 million per manufacturing facility per year. The benefits of reduced gunk emissions are thinly spread out among the 12 million or so people who live in the region where computer processors are manufactured. It is estimated that each of the 12 million residents living near a facility will typically incur around $50 per year in external costs associated with uncontrolled gunk emissions, mostly from occasional mild cold-like symptoms, but gunk is not known to be linked to any deaths, debilitating injuries, or birth defects.

   a. Using Oye and Maxwell's terminology, is this an example of a "Stiglerian" or an "Olsonian" regulatory situation? Carefully explain your reasoning.
   b. Describe the most likely political economic outcomes of proposed gunk-control regulation. Will regulation occur? If so, what form might it take, and how stable will it be? Carefully explain your reasoning.

3. Suppose that the standard industry process for transforming wood chips into pulp for paper manufacturing leads to "badstuff" being flushed into ad-

jacent bodies of water. Badstuff is estimated to create health- and food-related external costs of nearly $1 billion annually and is widely known to elevate cancer risks and birth defects in many localized "hot spots" around the country. Several firms have patented a new process for making pulp that eliminates badstuff pollution. Though this patented new process is more expensive than the current industry standard process, it is much cheaper than other existing methods of badstuff-free pulp processing. These firms would like to make money from the patent by leasing the technology to other pulp makers, and thus have an incentive to lobby for more stringent environmental regulations in order to create a market for their new technology. Because the benefits of cleaning up badstuff are large and concentrated on people who live in the hot-spot areas, pressure groups have developed around environmental groups, physicians groups, sport fishers, surfers, rafters, and concerned parents of small children. The firms that have developed a badstuff-free pulp-processing technology also have a concentrated benefit in more stringent regulation and have begun a high-profile lobbying and public information campaign in partnership with the other pressure groups.

a. How might this scenario be different from that described in problem (1) above? Using Oye and Maxwell's terminology, what aspects of this scenario are more Stiglerian than that in problem (1)? Carefully explain your reasoning.

b. Describe how the most likely political-economic outcome of proposed badstuff-control regulation might differ from that of gunk-control regulation in problem (1) above. Carefully explain your reasoning.

4. Alberty and VanDeveer (1996) have compared the political economics of the Montreal Protocol to that of international attempts at controlling greenhouse gas emissions. Greenhouse gases, primarily carbon dioxide, are emitted from the burning of fossil fuels, especially coal. Although North America and Western Europe have been responsible for approximately 60 percent of the human-caused increase in atmospheric carbon dioxide, developing countries such as India and China, which will be developing their coal resources, are expected to surpass the emissions levels of rich countries in the first third of the twenty-first century. These countries interpret attempts at controlling their coal-based economic development as another example of rich countries trying to keep poor countries from raising incomes and attaining international power.

a. Relative to the Montreal Protocol, is the international effort to control greenhouse gases more Stiglerian or Olsonian in nature? Why might the political economic outcomes be different than for CFCs?

b. In the late 1990s, BP Amoco and Royal Dutch Shell left the Global

Climate Coalition, an industry association that has lobbied heavily against the Kyoto Protocol for limiting greenhouse gases, and have signed on with the pro-treaty group International Climate Change Partnership. How might this development change your answer in (a) above? You can access information on the Business Environmental Leadership Council on the Internet site for the Pew Center on Climate Change (http://www.pewclimate.org/belc/index.html) to learn more about corporations that are supporting action on global warming.

Internet Links

Center for Public Integrity (http://www.publicintegrity.org/): A nonprofit, nonpartisan educational organization that conducts investigative reporting on the role and influence of campaign contributions in the political process.

International Political Economy Network (http://csf.colorado.edu/ipe/index.html): IPENet offers online discussion lists, archived articles, and links to electronic political economy journals, to political economy course syllabi, and to political economy degree programs. The site is provided by Communications for a Sustainable Future.

Montreal Protocol for Substances that Deplete the Ozone Layer (http://www.unep.org/ozone/montreal.htm): The primary site for information on the Montreal Protocol, maintained by the United Nations Environment Program.

Opensecrets.org—The Online Source for Money in Politics Data (http://www.opensecrets.org/home/index.asp): This site provides comprehensive information on campaign contributions, and is provided by the Center for Responsive Politics, which is a nonpartisan, nonprofit research group based in Washington, DC, that tracks money in politics, and its effect on elections and public policy.

Project Vote Smart (http://www.vote-smart.org/index.phtml): Project Vote Smart is a nonpartisan organization offering an Internet library of factual information on candidates for public office at the federal and state level. Coverage is provided in five basic areas: backgrounds, issue positions, voting records, campaign finances, and the performance evaluations made on them by various special interest groups.

Report on the Supply and Demand of CFC-12 in the United States, 1999 (http://www.epa.gov/ozone/geninfo/sdreport99.html): This EPA site includes information on estimated quantities of smuggled CFC-12.

The Positive Political Economy of Instrument Choice in Environmental Policy (http://ksgwww.harvard.edu/prg/stavins/choice.htm): An informative description of environmental political economy by Nathaniel O. Keohane, Richard L. Revesz, and Robert N. Stavins.

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8

Motivating Regulatory Compliance: Monitoring, Enforcement, and Sanctions

Introduction

To what extent do government administrative agencies monitor and enforce environmental regulations? Is there sufficient deterrence to prevent large-scale noncompliance by polluting industries? To answer these and other questions, we will first look at the economics of crime and then turn to a more detailed description of how the EPA and other agencies actually administer environmental law. We will also discuss the role of market-based reputational enforcement, voluntary compliance programs, and citizen lawsuits in creating an incentive for compliance.

The Economics of Crime

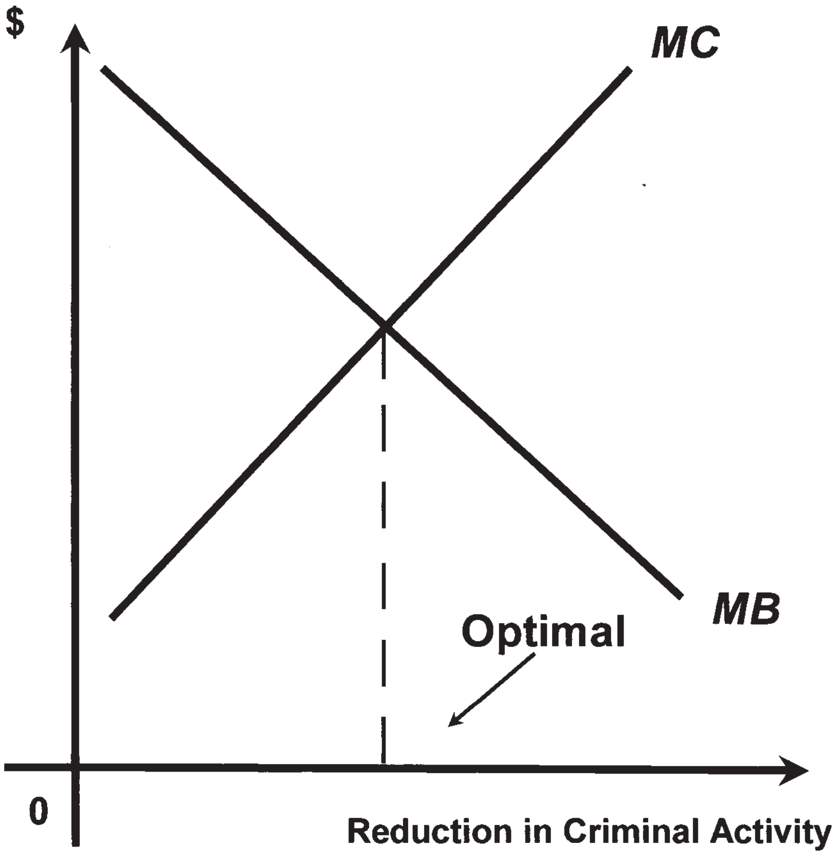
Law enforcement agencies have limited budgets and must choose the best way of allocating these scarce resources among competing ends. Some law enforcement activities are driven by legislative and other mandates, and others by political pressure. From an economic point of view, the efficient method of allocating law enforcement resources is to evaluate enforcement benefits and costs. For example, analysis of crime records may indicate that the incidence of property crime is highest during summer months and lower in the winter. In contrast, alcohol-related automobile accidents may peak around popular holidays. A police department that assigns a fixed number of personnel to property crime and drunk-driving deterrence throughout the year may instead find that seasonally adjusting the allocation of these enforcement resources can reduce the incidence of crime without increasing the overall law enforcement budget. Given that government funds are scarce, it is important from the perspective of society that law enforcement resources be spent efficiently. A municipal government, for example, must allocate its tax income over a set of obligations to its citizens that includes road building and maintenance, operation of public schools, law enforcement, and fire control, among others. Increasing the budget share allocated to law enforcement necessarily reduces the budget share allocated to other uses.

To illustrate the economics of law enforcement, consider the following example. To begin, suppose that law enforcement receives a very small budget share, while other municipal programs are well funded. In this case, there may be a relatively high level of crime, and so the *marginal benefits* of increasing law enforcement spending by some increment (such as hiring a new police officer) will tend to be high. Given that other municipal activities are relatively well funded, then shifting resources from other programs to fund this increase in law enforcement leads to a marginal *opportunity cost* of this shift (the forgone benefits of the money being spent on roads, schools, etc.) that is likely to be relatively low. In this case, spending more on law enforcement entails high marginal benefits and low marginal costs, and so from an economic perspective it would seem to make sense.

Now suppose that law enforcement receives a very large share of the municipal budget, while other programs are relatively poorly funded. In this case, the level of criminal activity is likely to be relatively low, as the high level of law enforcement activity will tend to create deterrence, and so the marginal benefits of increasing the law enforcement budget even more may be low. Given that other municipal activities are poorly funded, if we were to shift some additional resources away from these programs to fund additional law enforcement, the marginal opportunity cost of this shift will be relatively high. In this case, spending more on law enforcement entails low marginal benefits (there is already substantial crime deterrence from existing law enforcement activities) and high marginal costs, and thus would not seem to make sense from an economic perspective.

This hypothetical example illustrates several general relationships that economists consider to be important in determining the efficient level of law enforcement activity. First, the marginal benefits of law enforcement spending are presumed to start out high but to decline as more and more resources are allocated to law enforcement activities. Second, the marginal opportunity cost of law enforcement spending may start out low but will rise as more and more resources are allocated away from other beneficial uses to fund additional law enforcement. From a conceptual perspective, as marginal benefits decline and marginal costs rise, there will be a level of law enforcement

Figure 8.1 **Optimal Level of Crime Control**



spending where marginal benefits equal marginal costs. This is another application of the equimarginal principle, first used in chapter 4 to describe a firm's optimal (profit-maximizing) output level, and later used in chapter 6 in the discussion of the optimal (net benefit-maximizing) level of environmental protection or improvement. In the case of the economics of law enforcement, when resources are allocated to law enforcement up to the point where marginal benefit equals marginal cost, then total net benefits (total benefit – total cost) will be largest. Any further law enforcement spending will generate marginal benefits that are smaller than marginal costs, which reduces total net benefits in a manner similar to that shown in chapter 6. If society is using an efficiency standard, then the optimal level of law enforcement spending occurs where net benefit is maximized and marginal benefit equals marginal cost, as illustrated in Figure 8.1.

A primary goal of law enforcement is to create an adequate *deterrent* to criminal activity. To create a sufficient deterrent against violating environmental law, enforcement systems must create an *expected penalty* that exceeds the economic gain from violating environmental law. If those who violate environmental law seek to maximize the expected net benefits from their activities, and if the incentive to violate environmental law is to avoid the cost of compliance, then deterrence in any given time period requires that the following relation must exist:

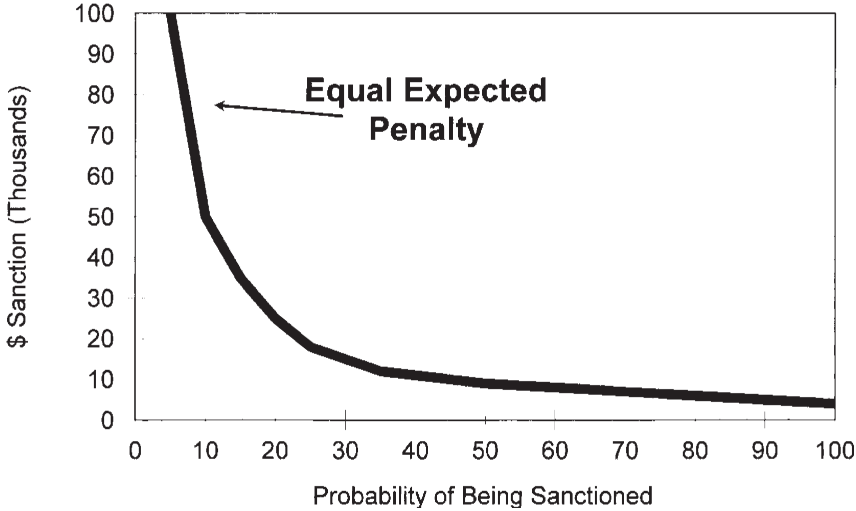
$$\text{Probability(detection)} \times \text{probability(sanction/detection)} \times \text{sanction} > \text{cost savings.}$$

"Probability(detection)" refers to the probability of the environmental violation being detected by those responsible for enforcing environmental law. "Probability(sanction/detection)" refers to the probability of the environmental violator being punished (sanctioned), which is contingent upon having been detected in violation of environmental law. To keep the analysis as simple as possible, it is assumed that only one sanction can be imposed. Note that, because the probability of detection multiplied by the probability of being sanctioned given detection is generally less than 1 (why?), the minimum sanction necessary for deterrence will exceed the cost savings from polluting.

Adequate deterrence exists when potential environmental lawbreakers evaluate the expected benefits and costs of violating the law and find that the crime does not pay—the expected costs exceed the expected benefits. The benefits of breaking the law are varied, but from the perspective of a polluter, they will include the cost savings from a lower level of pollution-control activities. The costs of breaking the law include *sanctions* such as jail time, fines, penalties, private lawsuits, and loss of reputation and goodwill. It is important to note, however, that the costs of lawbreaking activity are only realized when the lawbreaking activity is detected, which means that *expected costs* are weighted by the probability of the illegal behavior's being observed and a sanction imposed. If a law enforcement agency does not spend much time on monitoring, the agency must increase the size of the sanction to keep the *expected penalty* the same. Figure 8.2 illustrates an equal expected penalty curve, showing that as the probability of successful detection falls, the sanction must rise to keep the expected penalty constant.

It is tempting to believe that in practice we could maintain a given level of deterrence by reducing monitoring activities and increasing sanctions, as shown in the upper left-hand portion of the curve in Figure 8.2. This would save public funds that would otherwise be needed for monitoring activity. The problem with this idea is that in the event that a violation is detected,

Figure 8.2 **Equal Expected Penalty Curve**



courts may not be willing to impose large statutory penalties for modest violations. To do so would violate the legal norm that penalties should be proportionate to the violation. Moreover, if we reduce the intensity of polluter monitoring relative to other forms of law enforcement, then to maintain deterrence we may have to impose sanctions on moderate levels of pollution that are larger than the sanctions for more intensely monitored violations such as violent crime. In actual practice, judges and politicians will be unlikely to support large sanctions for modest violations, and therefore it is unlikely to be feasible to operate on the upper left-hand portion of the equal expected penalty curve. If society applies the legal norm of penalties being proportionate to the harms caused by the violation, then deterrence will only be maintained when society commits sufficient resources to monitoring activity.

It is sometimes argued that the sanction imposed on polluters should be equal to the economic gain from polluting, yet deterrence will fail if we ignore the probability of detecting and sanctioning polluters. For example, suppose that by being out of compliance with pollution laws, a firm can save $10 million each year in pollution-control costs. Suppose that the statutory penalty is set equal to the economic gain to the polluter from being out of compliance (in this case $10 million). Also assume that there is a 75 percent chance that the firm will be detected as being out of compliance and a 90 percent chance that a judge will impose the sanction if the violation is detected. Has effective deterrence been created? No, because the expected benefit of polluting is $10 million each year; the expected cost of polluting is:

$$0.75 \times 0.90 \times \$10 \text{ million} = \$6.75 \text{ million.}$$

Thus, it pays to be out of compliance, and no effective deterrence has been created. Even if the firm is risk-averse and places a subjective probability of 85 percent rather than 75 percent on the likelihood of detection, it still pays to pollute.

Criminal Penalties and Incarceration versus Fines and Monetary Damages

Fines and monetary damage claims generate lower social costs than does incarceration, as Becker (1968) has argued, because society must pay to keep someone behind bars, because criminal cases are more expensive to prosecute and more difficult to prove, and because the person is no longer generating taxable income. But there are a variety of reasons why fines may not generate sufficient deterrence:

- Statutory fines may be too low to provide a deterrent given existing levels of monitoring.
- The value of the lawbreaker's assets may be smaller than the fine.
- Violators may have a subjective probability of being caught that is less than the actual probability.
- Monitoring and penalties may be based on violators having a neutral attitude toward risk, when some violators may actually have a preference for risk.
- Fines may be bargained down in out-of-court settlements, or administrators and judges may fail to impose adequate penalties when violations are observed. Russell (1990) finds, for example, that from 1977 to 1983 the average fine per notice of violation (NOV) issued across various states was less than $100 in many cases and rarely exceeded $2,000. In many instances, fines were assessed in fewer than 10 percent of the cases in which NOVs were issued at the state level.
- A large component of a fine can often be shifted to insurers, consumers, or taxpayers. For example, monetary damages reduce corporate income and thus can be used as a corporate tax write-off.

A clear advantage of incarceration is that it cannot be shifted, as can fines. Moreover, successful criminal prosecutions create quite a bit of publicity, and the adverse publicity may generate an additional market-based reputational cost for the environmental criminal. Conversely, there are problems with using criminal sanctions and incarceration to create deterrence. As mentioned above, criminal sanctions impose incarceration costs on society, and the families of those who are incarcerated will experience a loss of income. In addition, criminal sanctions have a higher burden of proof (beyond a reasonable doubt) than do administrative fines or monetary penalties generated from civil lawsuits (preponderance of evidence). As a result, criminal cases are more costly to prosecute and may be less likely to succeed in passing the higher burden of proof.

Another problem with criminal sanctioning is that apparently judges have been hesitant to impose prison terms for environmental crimes. In particular, Mark Cohen (1992) found that out of a sample of 116 cases of companies successfully prosecuted for environmental crime in federal courts from 1984 to 1990, executives were sentenced to prison terms in only 25 (fines were issued in the remainder) and, of those, 23 were from "small" firms of less than $1 million in sales or with fewer than 50 employees. Finally, many have criticized the "club fed" minimum-security facilities at which many environmental and other "white-collar" criminals are imprisoned as not promoting much in the way of deterrence.

As Segerson and Tietenberg (1992) argue, the traditional penalty structure used in enforcement of environmental laws has involved monetary penalties imposed on firms rather than fines and prison terms imposed on individuals. The effectiveness of this approach in changing the behavior of employees who violate company policies on compliance with environmental law depends critically on firms being able to impose adequate internal sanctions on those employees responsible for the violation. In their model of internal firm organization, Segerson and Tietenberg discovered that traditional penalties operate efficiently only when employee behavior is fully observable and the firm's compensation structure is sufficiently flexible that it can shift penalties onto guilty employees. Yet, the same incentives can be provided by directly penalizing the employee. In practice, however, these conditions are unlikely to be met. They show that incarceration can be the socially efficient form of deterrence mechanism in more "real-world" circumstances.

Market-Based Reputational Enforcement and Voluntary Overcompliance

As we have seen, fines, monetary damages, and criminal penalties are coercive, costly, and will sometimes fail to foster deterrence. *Market reputation* provides an alternative method of aligning the incentives of firms with those of society. We know, for example, that many corporations care about how they are perceived, as evidenced by the substantial image advertising budgets of many oil, forest products, chemical-manufacturing, and other companies. A particularly striking example is offered by a 1996 civil rights settlement against Texaco. Texaco was involved in a civil rights lawsuit brought by several black employees. After approximately two and one-half years without a settlement, an incriminating tape surfaced in November 1996 that strongly supported the claims of the black employees. Boycotts were threatened by black leaders such as Jesse Jackson. Eleven days after the recording surfaced, and with mounting press coverage of the boycott threats, Texaco settled for $176 million. This costly settlement was widely seen as a way for Texaco to limit harm to its corporate reputation.

Market reputations are most likely to foster deterrence in an environmental context when the following conditions are met:

- Objective information is available on the environmental performance of firms at low cost.
- Consumers and environmentalists can be organized into an effective interest group capable of boycotting environmentally harmful products.
- Quality substitute products made by firms with an equivalent or better environmental record are readily available.
- A boycott imposes meaningful costs on firms with a poor environmental record, such as the loss of market share or an image-based price premium.

Examples of environmentalists using markets to create regulatory change have included dolphin-safe tuna-harvesting techniques and the discontinuation of the use of Alar in apple production. There are several practical problems that constrain the effectiveness of consumer boycotts, however, including the ability of firms to hide destructive practices through subcontractors or overseas production, and limits to the number of boycotts that consumers can juggle at any given time.

An increasing number of corporations are finding that an environmentally friendly reputation serves as a substitute for conventional advertising. For example, the Environmental Protection Agency (EPA) has a wide variety of voluntary pollution-control programs, described collectively as “Partners for the Environment.” The nationwide Partners for the Environment programs are summarized in Table 8.1. As the material in Table 8.1 indicates, the Partners for the Environment programs are focused on producing environmental improvements that are not currently required by regulation. A key benefit received by participating firms is the ability to self-identify as being in "overcompliance" with environmental law and thereby to improve their reputation. This reputational benefit is explicitly stated on the EPA Partners Internet site: "Showing statistically that your organization saved thousands of gallons of water or prevented thousands of tons of waste sends a clear 'green' message to your customers."

Some of the more prominent of these voluntary programs include the EPA's Common Sense Initiative, Energy Star, and Green Lights programs, the latter of which had more than 2,500 corporate, university, nonprofit, and government participants in 1997. Dolan (1997) observes that the Energy Star Program has partnership agreements with 85–95 percent of the office equipment market, and Energy Star products generate annual energy cost savings ranging from $20 (computer monitors) to $190 (large copiers). As of January 1998, approximately 10 percent of U.S. commercial and industrial office space was enrolled in the Energy Star Buildings program. The "33/50 Program" was the first of the EPA voluntary overcompliance programs, and it was designed to reduce the 1.5 billion pounds of 17 high-priority toxic chemical emissions identified in the 1988 Toxic Release Inventory by 33 percent in 1992 and by 50 percent in 1995. A total of 1,300 firms signed up with the 33/50 Program, and toxic emissions were ultimately reduced by 55 percent from 1988 levels. Once the goals were reached the program was discontinued.

Arora and Cason (1995) state that those companies that participate in the EPA voluntary overcompliance programs tend to be large firms in less concentrated industries (more "competitive"), and that *public recognition* (i.e., reputation) is an important element in fostering participation. The research nonprofit organization Resources for the Future (1997) evaluated the performance of the EPA's Common Sense Initiative, 33/50 Program, and Project XL, along with several other environmental, health, and safety programs. The researchers argue that these voluntary programs have for the most part had only a peripheral impact on solving important pollution problems. While some of the voluntary programs have had a positive impact, particularly 33/50, they warn that it is difficult to create strong incentives for industry action in the absence of legislation.

Private Auditing

There is a growing movement to have firms and other organizations develop environmental management systems that utilize private, third-party audits of their emissions and wastes. These include pilot programs by the EPA, various states, and the International Organization for Standardization.

Table 8.1

Summary of EPA Partners for the Environment Nationwide Programs

Program	Description
Agricultural programs	
AgSTAR	Promotes cost-effective methods for reducing methane emissions at dairy and swine operations through improved manure management.
Pesticide Environmental Stewardship	Promotes integrated pest management and reduces pesticide risk in agricultural and nonagricultural settings.
Ruminant Livestock Efficiency	Reduces methane emissions from ruminant livestock operations.
Air quality programs	
Indoor Environments	Promotes simple, low-cost methods for reducing indoor air quality risks.
Energy efficiency and global climate change programs	
Climate Wise	Reduces industrial greenhouse gas emissions and energy costs through comprehensive pollution prevention and energy-efficiency programs.
Coalbed Methane Outreach	Increases methane recovery at coal mines.
Energy Star	Maximizes energy efficiency in commercial, industrial, and residential settings by promoting new building and product design and practices.
Landfill Methane Outreach	Reduces methane emissions from landfills by installing products to capture gases and produce electricity, steam, or boiler fuel.
Natural Gas STAR	Encourages natural gas industry to reduce leaks through cost-effective best management practices.
State and Local Outreach	Reduces greenhouse gas emissions from states and local communities by empowering officials with information and technical assistance.
Voluntary Aluminum Industrial Partnership	Reduces per-fluorocarbon gas emissions from aluminum smelting.
Labeling Programs	
Consumer Labeling Initiative	Promotes easier-to-read labels on household cleaners and pesticides to improve consumer safety.
Pollution Prevention Programs	
Design for the Environment	Helps businesses incorporate environmental considerations into the design of products, processes, and technical and management systems.

Environmental Accounting	Increases business understanding of environmental costs and incorporation of these costs into routine operations.
Environmental Technology Verification	Verifies the performance characteristics of commercial-ready environmental technologies through the evaluation of objective and quality-assured data.
Green Chemistry	Promotes the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances.
Regulatory innovation programs	
Common Sense Initiative (CSI)	Develops sector-based environmental management strategies tailored to the auto manufacturing; computers and electronics; iron and steel metal finishing; petroleum refining; and printing industries.
Environmental Leadership	Recognizes and rewards facilities that demonstrate strong environmental performance and commit to go beyond compliance with existing requirements.
Project XL	Allows companies to test alternative approaches that achieve cleaner and cheaper environmental results than would be realized under existing requirements.
Waste management programs	
Waste Minimization National Plan	Reduces persistent, bioaccumulative, and toxic chemicals in hazardous waste.
WasteWise	Encourages business, government, and institutional partners to reduce municipal solid waste through waste prevention, recycling, and buying/manufacturing products with recycled content, benefiting their bottom lines and the environment.
Water programs	
Adopt Your Watershed	Challenges citizens and organizations to join EPA and others who are working to protect and restore rivers, streams, wetlands, lakes, groundwater, and estuaries.
Water Alliance for Voluntary Efficiency (WAVE)	Promotes water efficiency in hotels, schools, universities, and office buildings.

Source: U.S. EPA (http://www.epa.gov/partners/).

Environmental audits are conducted by independent third-party auditing companies, with neutrality similar to that of auditors of financial statements for the shareholders of publicly traded corporations. There are a number of reasons why firms may want to utilize private third-party environmental audits. One is that the audit may reveal substandard practices that significantly elevate the chances of an environmental disaster, such as the *Exxon Valdez* oil spill, which can cost the company enormous amounts of money in fines and damage claims. For example, having a certified environmental management system utilizing neutral third-party environmental auditors demonstrates a higher standard of care, which from a legal perspective can shield a company from punitive damage claims. Moreover, failure to reveal a publicly traded corporation's excessive exposure to such financial hazards to its shareholders can result in the firm's being further exposed to class-action lawsuits brought by shareholders. Audits can also help companies identify areas where costly waste of energy or materials can be reduced.

A potential problem with environmental audits can arise if the information can be used to fine a company or sue for damages resulting from discovery of past noncompliance or past tortious acts. To maintain the incentive for environmental auditing, currently about 15 states grant environmental audit privilege, which means that the right to employ a private third-party environmental auditor is deemed more important from a policy perspective than the information generated by the audit. This is the privilege given to disclosure to one's spouse or attorney or priest. Currently, the federal government does not recognize environmental audit privilege. About 25 states currently grant amnesty to firms that discover violations of environmental law through the use of an environmental management system and correct the problems causing the compliance failure.

The EPA's Environmental Leadership Program (ELP) was designed to promote the development of environmental management systems and independent environmental audits. Ten private facilities and two government facilities participated in the pilot phase of the ELP, which ended in 1996. Unfortunately, the ELP has not been implemented on a permanent basis; nevertheless, the EPA has a voluntary environmental audit policy. In 1998, at least 200 companies disclosed potential violations at 950 facilities under the auspices of the EPA's self-disclosure (audit) policy. Ever since the inception of the audit policy, a total of 450 companies have disclosed violations at 1,870 facilities and relief was granted to 164 companies at 540 facilities that returned to compliance. Likewise, since 1991 it has been the policy of the U.S. Department of Justice to encourage self-auditing, self-policing, and voluntary disclosure of environmental violations by the regulated community. The Department of Justice encourages self-auditing and voluntary disclosure by indicating that these activities are viewed as mitigating factors in the department's exercise of its criminal environmental enforcement discretion.

Incentive Enforcement Systems

Unlike environmental audits, which are designed to help firms identify wasteful and hazardous processes, *incentive enforcement* systems are designed to give polluting firms an incentive to comply with environmental regulations, thus reducing monitoring and enforcement costs while maintaining deterrence. To illustrate how they work, consider the following regulatory scheme. The Clean Water Act, the 1990 Clean Air Act (CAA) amendments, and the enabling legislation for the Toxics Release Inventory all require that firms monitor and self-report their emissions. Falsifying is a criminal offense, primarily followed up on by citizen groups in citizen lawsuits. Moreover, both the EPA and the Department of Justice have developed incentive policies in which those who self-report and resolve environmental violations can qualify for reduced or suspended penalties.

Economists have also researched the question of incentive-based enforcement systems. For example, consider the following system:

- Firms self-report their emissions and pay fines if they overemit.
- The government more vigorously monitors the *lower* the *reported* level of emissions.
- If actual emissions exceed reported emissions, the firm pays additional pollution fines plus an additional fine for having made a false claim.

The advantage of this scheme, devised by Malik (1993), is that with some level of government monitoring and an adequate penalty for falsification, the scheme gives firms an incentive to report their actual emissions and lowers the cost of government monitoring efforts.

EPA Enforcement

The EPA does not have the resources to monitor all pollution sources for compliance with environmental law. Monitoring resources tend to be focused on the major sources of air and water pollution. In the case of water pollution discharges, the EPA requires by law that the firms submit to the EPA a record of the nature of the discharge, and that each firm report the status of its compliance with the pollution permit that it has been given. The nature and the source of the pollution affects the feasibility of effective enforcement. Hazards that arise on a decentralized basis—such as toxic wastes, radon in homes, and asbestos in buildings—often pose substantial enforcement problems because of the large number of pollution sources involved and the difficulty in monitoring the responsible parties. The process of screening chemicals and regulating the sale of commercially produced chemicals is a relatively easy monitoring function for the EPA, as is the process of monitoring the use of hazard-warning labels. It is much more difficult to monitor to assure that hazardous products are used appropriately. Moreover, the disposal of chemical containers and the dilution of insecticides are among the decentralized activities that pose nearly insurmountable monitoring problems. Providing hazard information and hoping that people adopt the appropriate ethic may be all that an administrative agency can do in such cases. To increase the impact of the federal government's enforcement efforts, both the EPA and the Department of Justice have recently instituted incentive policies in which firms and individuals that self-report and resolve violations can qualify for reduced or suspended penalties.

EPA Enforcement Tools

The EPA has a variety of enforcement tools available. Most commonly, the EPA

- inspects a firm;
- requests that a firm provide data; and
- discusses pollution-control measures with the firm.

In terms of EPA sanctions, there are two options:

- impose administrative penalties, usually modest in size and limited in terms of the circumstances in which they can be levied;
- refer cases to the Department of Justice for criminal or civil prosecution.

Under the 1990 Clean Air Act amendments, the EPA was granted new administrative authority to assess penalties without filing a court case and bringing in the Department of Justice. This administrative authority allows the EPA to order payment of penalties of up to $200,000 and/or order that violations be corrected. Those who receive an EPA order can appeal to an administrative law judge. The EPA can also issue "field citations" of up to $5,000 per day to violators when an EPA inspector finds certain types of violations, such as nonfunctioning monitoring equipment. These new authorities allow the EPA to act on smaller cases without having to incur the time and expense of a federal court action. The amendments also expand the notion of "emergency actions" to include threats to the environment, rather than specifically to human health. These emergency orders have fines that range from $5,000 to $25,000 per day, and they add a criminal penalty of up to five years in prison for knowingly violating an emergency order. Other criminal penalties include five years for knowingly and seriously violating the CAA, doubled for second offenses; 15 years for knowingly releasing hazardous air pollution that places people in imminent danger of death or bodily injury; one year for negligent releases; and one year for tampering with a monitoring device and criminalizing the falsification of pollution data.

EPA Enforcement Trends

Beginning in the 1980s, the EPA became more concerned about toxic substances and hazardous wastes. The Resource Conservation and Recovery Act of 1976 focused on the identification and transportation of hazardous wastes. The Superfund program, established in 1980, focuses on hazardous waste site cleanup. The Toxic Substances Control Act requires pre-manufacture evaluation of all new chemicals and provides the EPA with the authority to regulate existing chemicals. All three areas have exhibited substantial growth. Russell (1990) offers an accounting of EPA civil referrals and administrative actions through 1990. Between 1978 and 1988, for example, the EPA typically referred approximately 100 air pollution cases annually, though this fluctuated between 36 (1982) and 149 (1979). A roughly similar pattern held for water pollution cases, while hazardous waste referrals increased from 53 in 1980, when the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) was passed, to 143 in 1988. Total civil referrals rose from a handful in the early 1970s to nearly 400 by 1988. During this same period, there were about ten times as many administrative actions initiated by the EPA. Interestingly, while in the 1970s the most common administrative action occurred under the Federal Insecticide, Fungicide, and Rodenticide Act (between 860 and nearly 2,500 annually), by the late 1980s most such actions occurred under the Clean Water/Safe Drinking Water Acts. From 1984 through 1988, total administrative actions ranged between a low of 2,609 in 1985 and a high of 3,124 in 1984. In 1998, the EPA concluded 3,479 formal actions against environmental violators, issued 1,400 administrative penalty orders, and referred 411 civil cases and 266 criminal cases for prosecution by the Department of Justice. A total of $91.8 million in civil penalties and $92.8 million in criminal penalties were imposed in 1998 (USEPA 1999).

One notable pattern in both civil referrals and administrative actions was a sharp decline during the early 1980s. Anne Gorsuch, appointed to head the

EPA by President Ronald Reagan, sought to decrease the burden of regulations on business by scaling back enforcement efforts. In 1983, Gorsuch was replaced by William Ruckelshaus, who restored enforcement efforts to some extent and redirected the agency toward the new class of hazardous materials.

Selected Civil and Criminal Case Summaries from the Department of Justice

The civil and criminal case summaries in this section are taken from Department of Justice records.

A 1999 settlement with seven heavy-duty diesel engine manufacturers led to the largest Clean Air Act (CAA) penalty up to that time. The settlement resolved charges that the companies violated the CAA by installing software that allowed engines to meet EPA emission standards during testing but disabled the emission control system during normal highway driving. The settlement is expected to prevent 75 million tons of nitrous oxide air pollution over the next 27 years and reduce such emissions from diesel engines by one-third by 2003. The initiative also resulted in an $83.4 million penalty payment, the largest civil environmental penalty imposed up to that time.

In 1999, the Fourth Circuit Court of Appeals upheld imposition of a Clean Water Act (CWA) civil penalty in excess of $12 million, the largest penalty awarded under the CWA up to then. The appellate court affirmed a lower court ruling that Smithfield Foods and its subsidiaries violated the CWA by discharging illegal levels of phosphorous, ammonia, cyanide, and fecal coliform from their slaughterhouse into the Pagan River. The court held that an agreement between the company and the Commonwealth of Virginia that allowed Smithfield to exceed its permit limits did not excuse Smithfield's violations because the agreement was not part of the permit approved by the EPA, and because Virginia law was not comparable to the federal law.

In August 1999, a federal district court in Arkansas entered final judgment for the United States in the amount of $100.5 million, plus future costs, concluding 18 years of litigation at the Vertac Superfund Site. The Vertac Site, the location of a herbicide manufacturing plant that operated from the 1960s to the 1980s and manufactured, among other things, Agent Orange, was one of the worst dioxin-contaminated sites in the country. This was the largest adjudicated Superfund judgment up to that time.

In October 1998, the Department of Justice entered into a consent decree with the FMC Corp. resolving numerous violations of the Resource Conservation and Recovery Act (RCRA) at an FMC facility on the Shoshone-

Bannock Tribe's Fort Hall Indian Reservation in Pocatello, Idaho. The facility is the world's largest producer of elemental phosphorus, which is used in detergents, beverages, foods, synthetic lubricants, and pesticides. The most serious of the RCRA violations involved mismanagement of phosphorus wastes in ponds; these wastes burn vigorously when exposed to the air, and they also generate toxic gases that can cause serious health and environmental problems. The FMC Corp. has agreed to spend approximately $158 million to settle this case and will pay another $11.8 million as a civil penalty, the largest obtained under RCRA up to that time.

In January 1999, Buddy Frazier and his associates, Chance Gaines and James Bragg, were sentenced to prison for 30, 33, and 24 months, respectively, for multiple asbestos work practice and worker identification violations in connection with the demolition of a manufacturing building in Marshfield, Wisconsin. The defendants had recruited untrained, homeless men from a community kitchen in Chattanooga, Tennessee, obtained fraudulent asbestos training identification cards for these workers, and directed them to strip asbestos pipe insulation without first wetting the material, thereby exposing the men to the severe health risks associated with asbestos inhalation. In connection with this prosecution, the Environment and Natural Resources Division of the Department of Justice launched a nationwide project with the EPA and the National Coalition for the Homeless to halt the exploitation of homeless and itinerant workers for illegal asbestos work.

In September 1996, U.S. District Court Judge Hector Laffitte sentenced three corporations—Bunker Group Puerto Rico, Bunker Group Incorporated, and New England Marine Services—to each pay a $25 million fine and complete a five-year term of corporate probation. On April 25, 1996, a federal jury convicted the companies of sending out an unseaworthy vessel, negligently discharging oil, and failing to notify the U.S. Coast Guard that a hazardous condition existed on the vessel. As a result, 750,000 gallons of oil were spilled into the waters off Puerto Rico and onto its popular Escambron Beach at the height of the tourist season in January 1994. This was one of the largest fines ever imposed for an environmental crime.

The Environmental Crimes Section of the Department of Justice achieved a significant victory in *United States v. Robert Brittingham and John LoMonaco*. In 1993, as a result of a jury conviction on 16 counts of Resource Conservation and Recovery Act violations, $6 million in criminal fines were imposed on the highest-ranking officials of a major corporation ever convicted of criminal environmental offenses. The chairman of the board of directors for Dal Tile Corp., the largest ceramic tile manufacturer in the nation, was fined $4 million, and the president of the same corporation was fined $2 million. Five years' probation was also imposed upon the defendants, during which time they must expend $6 million from personal funds to develop and institute a program to test the lead levels in children and lead abatement in residences of a Dallas, Texas, neighborhood.

In *United States v. Montrose Chemical Corporation,* the Environmental Enforcement Section of the Department of Justice resolved a CERCLA issue involving a major corporate chemical plant in 1993. The United States District Court for the Central District of California entered a consent decree in this case resolving the claims of the United States and the State of California against settling local governmental entities with respect to their liability for natural resource damages resulting from DDT and PCB contamination of the environment from facilities in and around Los Angeles. The litigation was brought on behalf of the federal and state natural resource trustees seeking damages under Section 107(a)(4) of CERCLA. Under the consent decree, the settling entities paid federal and state trustees $42.2 million for natural resource damages. The suit also resolved a second claim for relief brought by the United States on behalf of the EPA for response costs in connection with the Montrose Chemical Corp. plant site, a National Priority Listed Superfund cleanup site. The settling entities paid $3.5 million to the EPA for response costs at the site.

In response to a major CWA violation, the Environmental Defense Section of the Department of Justice sued a subsidiary of Westinghouse Electric Corp. for unpermitted filling of wetlands in Bonita Springs, Florida, in *United States v. Westinghouse.* Westinghouse illegally filled 15 acres of isolated wetlands near the Gulf of Mexico in connection with the development of an 1,800-acre commercial, recreational, and residential complex known as Pelican Landing. The consent decree provides that Westinghouse will (1) fully restore the illegally filled wetlands; (2) undertake a wetlands enhancement project on 98 acres of wetlands on the development site, which will include the removal of exotic vegetation, the placement of extensive marsh and hardwood plantings, the creation of lakes and ponds for habitat diversity, and the preservation of the wetlands in perpetuity through the conveyance of a conservation easement; and (3) pay a $199,088 civil penalty to the United States Treasury. The total value of the settlement, estimated to be $1.3 million at the time, made it the second largest judgment ever obtained by the United States in a civil enforcement action under Section 404 of the Clean Water Act.

California Enforcement

Most California environmental statutes contain provisions allowing for criminal liability of both companies and individuals who violate these statutes. Civil liability in the form of civil penalties and injunctive relief can also be imposed. Criminal penalty provisions are included in the following California environmental and other related statutes (and their federal counterparts):

- The Porter-Cologne Water Quality Control Act (federal counterpart: Clean Water Act [CWA]). California is authorized to implement the provisions of the CWA in its state waters. California law provides for substantial felony penalties for knowingly violating its own Porter-Cologne Water Quality Control Act.
- California Clean Air Act (federal counterpart: Clean Air Act [CAA] and amendments). The California Clean Air Act provides for criminal penalties for violation of a permitee's emissions permit. The criminal sanction is increased if the violation occurred knowingly or as a result of negligence. An emission that causes or threatens serious bodily injury or death can result in a 15-year prison term and a fine of up to $1 million.
- The Hazardous Waste Control Act (federal counterpart: Resource Conservation and Recovery Act [RCRA]). Under California law, criminal penalties exist for failure to properly transport, store, handle, or maintain records of hazardous waste. This law also provides for civil liability and injunctive relief that can be imposed cumulatively with the criminal penalties. Violations that result in great bodily injury or cause a substantial probability of death can result in up to three years in prison and fines of $250,000 per day of violation.
- The Hazardous Substances Account Act (federal counterpart: Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA]). Under California law, criminal penalties exist for failing to report a release, or a threatened release, of a hazardous material, for particular failures to file disposal reports, and for certain record-keeping violations. Penalties for subsequent violations range up to fines of $50,000 per day and imprisonment for two years.
- California Corporate Criminal Liability Act. Also known as the "be a manager, go to jail" law, it makes corporations and their managers criminally liable when they fail to warn their employees and report to a California regulatory agency the existence of "serious concealed dangers of which the corporation and its managers have actual knowledge. . . . A serious concealed danger is normal or foreseeable use of a product or practice that creates a substantial probability of death, great bodily harm, or serious exposure to an individual to whom the danger is not readily apparent" (Pen C sect. 387[b][3, 4]). Up to three years in prison and fines of $25,000 can be imposed on individuals, and fines of up to $1 million can be levied on corporations. (*Source:* Bancroft-Whitney's *California Civil Practice—Environmental Litigation*, 1993.)

Compliance

The Clean Water Act, the 1990 Clean Air Act amendments, and the enabling legislation for the Toxic Release Inventory all require that firms monitor and self-report their emissions. Falsifying is a criminal offense, primarily followed by citizen groups in citizen lawsuits.

One issue is initial compliance—has the firm installed the necessary technology and/or established the necessary monitoring/control functions? Another issue is compliance over time—"continuous" compliance. There are no comprehensive estimates of the extent of continuous compliance. There are indications, however, that while initial compliance rates tend to be high (80–90 percent), continuous compliance rates are much lower, on the order of 45 percent or so (Russell 1990). Why might compliance rates be exaggerated? Perhaps because the EPA has commonly relied upon *preannounced* on-site inspections of stationary/point-source polluters, giving firms an opportunity to install/fix/turn on pollution-control equipment. Typical inspection rates are once a year, with the inspection usually restricted to making sure that pollution-control equipment is functioning properly.

According to the EPA (USEPA 1999), regional EPA staff conducted 23,237 inspections in 1998, an increase of 19 percent over 1997. Nevertheless, these inspections covered only 1.7 percent of the 1,366,634 core regulated facilities that were required to comply with environmental regulation (or just 0.29 percent of all core and non-core regulated facilities). The EPA found a wide range of different rates of significant noncompliance with environmental regulations in 1998. For example, 11.8 percent of automobile assembly facilities, 19 percent of pulp manufacturers, 45 percent of petroleum refineries, and 72.7 percent of integrated iron and steel mills were found to be in significant noncompliance with air quality regulations. Compliance with water quality law appears to be better than for air quality. For example, none of the automobile assembly facilities, 4.7 percent of the pulp manufacturers, 11.8 percent of petroleum refineries, and 39.1 percent of integrated iron and steel mills were found to be in significant noncompliance with water quality regulations. Overall, in 1998 the EPA estimated that 7 percent of air pollution sources were found to be in significant noncompliance, though a review by the U.S. Inspector General suggests that violations are underreported. Approximately 20 percent of waste combusters and landfill operators were in significant noncompliance with the Resource Conservation and Recovery Act, and about one-third of tank owners and operators are likewise out of compliance with the Underground Storage Tank program requirements. Finally, about a quarter of all drinking water systems are out of compliance with the Safe Drinking Water Act.

The EPA has stated that of the thousands of CAA violations it finds yearly, only about 500 or so are serious enough to represent "significant noncompliance." For Clean Water Act self-monitoring, firms are required to report discharges monthly. In the mid-1980s, continuous compliance rates reported for the pulp and paper industry were between 75 and 85 percent, with significant noncompliance rates about 6 percent (Magat and Viscusi 1990). One problem is that the EPA has a difficult time enforcing environmental regulations at military/energy/government-contractor facilities (e.g., Rocky Flats, CO). Another problem is that it is unclear whether the citizen-suit provisions of federal environmental law can bind state agencies. In other words, states themselves may violate federal environmental law, and there is a question as to whether the citizen-suit provisions of these federal environmental laws can be employed against states that fail to abide by them.

Citizen Suits

Most environmental laws have provisions that allow for private citizens to sue polluters for violating statutes. The possibility of citizen lawsuits leverages government enforcement efforts by empowering people who are directly harmed by pollution to do something about it. These suits can force compliance, may require damages restitution, and can impose sanctions as well—for hazardous waste (RCRA) and Superfund (CERCLA). Successful citizen lawsuits are difficult, however, because of the evidentiary requirements. Such suits have been most common in CWA cases where monthly self-reporting is required and where waterways can be monitored by private citizens. Citizen suits are very important because they can counteract political pressure brought to bear on the EPA and the revolving-door motive for ignoring pollution violations.

Prior to the 1990 CAA amendments, citizens could only sue violators to force compliance; under the 1990 Amendments, citizen suits can include cash penalties, which, if the suits are successful, go into an enforcement fund. Congress authorized awards of up to $10,000 to citizens who provide information leading to criminal convictions or civil penalties for violation of the CAA. Unfortunately, state and federal employees are exempt. Recent state law in Arizona has eliminated the right of citizens to sue a company for polluting private or public property. The public may still sue the state to take action, but only if the state agrees that there has been a violation. Thus, if the state decides to ignore violations, citizens in Arizona no longer have recourse through citizen suits.

Summary

- The economics of crime is such that the marginal benefits decline as more and more enforcement effort is exerted, while the marginal costs tend to rise. As a result, the level of enforcement activity that maximizes total net benefits will generally imply less than complete prevention of illegal activity.

- Fines and prison time are the common ways that state and federal agencies enforce environmental laws. Although fines generate fewer social costs and can be imposed with a lower burden of proof, prison time cannot be shifted onto insurance companies, consumers, or taxpayers and thus can have a substantial deterrent effect on individuals.
- Deterrence occurs when crime does not pay—specifically, when the probability-weighted (expected) penalties associated with a violation exceed the gains from being out of compliance. The expected penalty is the monetary or criminal sanction, weighted by the probability of detection and the probability of the penalties actually being imposed given detection. Because the probability of being caught and penalized is less than 100 percent, the actual penalties that are imposed must exceed the gain from being out of compliance. In the past, fines have generated inadequate deterrence, especially at the state level.
- Market reputations can also play a role in providing an incentive for firms to be "environmentally friendly." Consumer boycotts are one example, and voluntary overcompliance programs such as the EPA's Green Lights Program can act as substitutes for image advertising. Consumers must be environmentally conscious and well-informed for these reputational systems to function.

More recent federal and state environmental laws have increased both the level of fines and the extent of criminal penalties associated with environmental law violations. Both the EPA and the Department of Justice have developed incentive policies in which those who self-report and then resolve violations of environmental law can qualify for reduced or suspended sentences.

Incentive schemes have also been developed and implemented in laws such as the Clean Water Act that require self-reporting and provide for penalties for false reporting. These schemes have the potential for generating deterrence while saving the government some monitoring costs.

Review Questions and Problems

1. Suppose that a firm can increase its profits by $1 million each year by choosing not to comply with environmental regulations. The company is an expected profit maximizer. The probability that the firm will be detected and found to be out of compliance is 40 percent, and the prob-

ability that a judge will impose a penalty given detection is 75 percent. If the only penalty is a fine, what is the minimum fine necessary to get this firm to comply with environmental regulations?

2. Suppose that a company can increase its profits by $2 million each year by choosing not to comply with environmental regulations. The firm, an expected profit maximizer, anticipates that if it is detected and found to be out of compliance, it will have to pay a penalty of $3 million. If the only penalty is this fine, what is the minimum probability of detection and being fined necessary to get this company to comply with environmental regulations?
3. Economist Gary Becker has argued that fines are a more efficient form of penalty than prison terms. While fines can be calibrated to create deterrence, prison terms create higher social costs because they eliminate a person's productive income and require society to pay tens of thousands of dollars annually to hold the person in prison. Give some reasons why there may be economically good arguments for making environmental violations punishable by prison terms.
4. Go to the Internet site for the Environmental and Natural Resources Division of the U.S. Department of Justice (http://www.usdoj.gov/enrd/index.html). Going beyond the examples given in the textbook, find an example of a recent and significant civil penalty or criminal sentence being imposed for violation of environmental law. Summarize the key elements of the case, including the name of the company or individual, the relevant environmental law, the nature of the violation, and the penalty imposed. Environmental litigation summaries for 1999 can be found at (http://www.usdoj.gov/enrd/FY99sum.htm), though you should use more summaries for more recent years if they are available.

Internet Links

Code of Federal Regulations (CFR) (http://www.access.gpo.gov/nara/cfr/): Read about actual monitoring procedures and administrative and criminal penalties embedded within various environmental regulations. The Clean Air Act, for example, is contained in Chapter 85 of Title 42 of the CFR.

Cornell University Legal Information Institute's Coverage of Environmental Law (http://www.law.cornell.edu/topics/environmental.html): Read about federal and state statutory environmental law, major federal and state court decisions having to do with the environment, and international environmental law.

Environmental and Natural Resources Division of the Department of Justice (http://www.usdoj.gov/enrd/index.html): Areas of responsibility include litigation concerning the protection, use, and development of the nation's natural resources and public lands, wildlife protection, Indian rights and claims, cleanup of the nation's hazardous waste sites, the acquisition of private property for federal use, and defense of environmental challenges to government programs and activities. This agency is termed "the nation's environmental lawyer."

Environmental Investigation Agency (http://www.eia-international.org/): The Environmental Investigation Agency (EIA) is an independent, international campaigning organization committed to investigating and exposing environmental crime.

EPA Office of Enforcement and Compliance Assurance (OECA) (http://es.epa.gov/oeca/index.html): Ensures compliance with the nation's environmental laws. Employing an integrated approach of compliance assistance, compliance incentives, and innovative civil and criminal enforcement, OECA and its partners seek to maximize compliance and reduce threats to public health and the environment.

EPA Partners for the Environment Programs (http://www.epa.gov/partners/): Read more about EPA-sponsored voluntary overcompliance programs.

OECA Accomplishments Report and Program Highlights (http://es.epa.gov/oeca/oecaAA.html): Read about administrative actions, penalties, and criminal referrals by the EPA.

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9

Incentive Regulation: Economic Instruments for Environmental Protection and Resource Management

Introduction

Broadly speaking, incentive regulation is concerned with the design of regulatory schemes that use economic instruments such as prices, taxes, subsidies, bonds, liability, or markets to align individual incentives with the common good. Many incentive regulatory schemes are indirect; policymakers control pollution emissions or other environmental standards indirectly by modulating incentives rather than through direct controls and standards. A common example is the can and bottle redemption deposit schemes used by states such as California, Michigan, and Oregon to promote recycling, thus limiting littering and landfill flows.

In California, for example, when one purchases a canned or glass-bottled soft drink or beer, included in the purchase price is a return deposit, such as those charged by equipment rental firms to assure that the equipment is brought back in good condition. This deposit is returned when the empty beverage container is taken to a recycling center. Glass and aluminum container deposits are a form of indirect control and can be contrasted with a direct-control requirement that mandates the recycling of glass and aluminum containers.

Another example of incentive regulation is the German "take-back" system (discussed in chapter 14), whereby manufacturers are required to take back the products that they make once they are worn out. The take-back program gives manufacturers an incentive to design products for low-cost reuse or recycling, and so is an indirect way of lowering the cost of materials in the reuse and recycling process. Liability standards and the potential for civil and criminal penalties offer another form of incentive regulation, as described in chapter 8. Still another example of incentive regulation is offered by funding garbage collection based on per-bag charges rather than through a fixed fee. The per-bag fee creates an indirect incentive to reduce the amount of garbage created by households.

A summary of some regulatory schemes that use various economic instruments to foster more environmentally friendly behavior is given in Table 9.1.

It is beyond the scope of this chapter to provide a complete accounting of the various incentive systems. Instead, this chapter will focus on two prominent forms of market-based environmental policy instruments, namely marketable pollution allowances and environmental taxes and subsidies. Some additional incentive schemes will be discussed in chapter 14.The discussion on environmental taxes builds on the theoretical foundation regarding externalities and Pigouvian taxes that was established in chapter 4.

Early environmental regulation has been criticized for its lack of beneficial incentives. The common approach was to use direct controls, also known as "command and control" regulation. Command-and-control regulation specifies how pollution is to be reduced through the application of uniform standards for firms, most prominently technology-based ("technology-forcing") or performance-based standards. Technology-based standards specify the methods and equipment that firms must use to comply with environmental regulation. Performance-based standards set uniform control targets for all regulated firms, but unlike technology-based standards, companies are given some choice over how the target is actually met (Stavins 2000). An example of a technology-based standard is the regulatory requirement that automobile manufacturers install catalytic converters rather than allow automobile companies to find the cheapest or most effective method of control. Performance-based standards that establish uniform control targets for particular industries and pollutants do not allow for the trading of allowed emissions across sources.

There are at least two problems with command-and-control regulation. First, command-and-control regulation tends to lock-in specific environmental technologies, and therefore retards the development of new and improved methods of pollution control. Second, as we will see in the next section of the chapter, uniform performance standards imposed on an industry in which firms have widely different pollution abatement costs results in a higher cost

Table 9.1

Summary of Economic Instruments for Environmental Protection and Resource Management

Instrument	Effects and impacts
Allowance trading systems	Lowers the cost of complying with environmental regulations
Environmental bonds (such as deposit-refund systems)	Fosters deterrence and provides funds for cleanup, restoration, and mitigation; promotes recycling
Environmental liability systems	Fosters deterrence and provides funds for cleanup, restoration, and mitigation
Market-based reputations	Environmentally conscious consumers reward "green" businesses
Property rights systems	Allows for effective resource governance, may prevent tragedy of the commons, and can create an incentive for productivity-enhancing investments
Pollution or effluent taxes and use fees	Reduces market distortions by internalizing exernalities and causing price to reflect marginal social cost; promotes less-harmful alternatives
Subsidies, loans, and grants for environmentally friendly investments	Promotes investment in clean technology and voluntary overcompliance

for achieving a given level of aggregate control. One example of the problems associated with using command-and-control environmental regulation is provided by the original Clean Air Act (CAA) of 1970 (Ackerman and Hassler 1981). At the insistence of U.S. senators from eastern states with high-sulfur coal, the CAA required that costly scrubbers be installed on coal-burning electricity-generating facilities, even though many could have generated the same cleanup by shifting to low-sulfur coal. While this requirement was politically efficient—the CAA could not otherwise have passed Congress—it fails to be economically cost efficient. In his survey of eight empirical studies, Tietenberg (1980) found that the ratio of aggregate pollution abatement costs under command-and-control regulation to that of a least-cost benchmark method of control ranged from 1.07 for sulfate emissions in the Los Angeles basin to 22.0 for hydrocarbon emissions at all U.S. Du Pont chemical manufacturing facilities. Thus, there are potentially large cost savings to be achieved from more flexible alternative regulatory systems.

The market-based environmental policy instruments described below differ from traditional command-and-control regulatory schemes in several ways. Stavins (2000) argues that market-based environmental policy instruments are regulations that encourage behavior through market signals rather than through explicit directives regarding pollution-control levels or methods. Marketable allowance systems are one type of market-based instrument embedded in the structure of an overall emissions reduction program, but which allows the degree of abatement to vary across sources in a manner that reduces overall compliance costs. Marketable allowance systems regulate the quantity of emissions, but generally do not force the use of a particular technology. Environmental taxes, such as those on pollution emissions, regulate the price of emissions and afford companies an incentive to reduce their tax liability by reducing their emissions, thus indirectly reducing emissions. In addition, pollution taxes result in market prices that more closely approximate the marginal social cost of production and so make cleaner alternative technologies more price competitive. Finally, because pollution taxes do not mandate a particular technology, they create a dynamic incentive for research and development (R&D) in ways to reduce the cost of cleaner technologies.

We begin this chapter with a discussion of marketable pollution allowances and their cost-saving properties, and we move on to describe various environmental taxes and emission charges.

Marketable Pollution Allowances

There have been a number of policy experiments with marketable quotas or allowances, including individual transferable quotas (ITQs) used in fisheries management (chapter 5), marketable development rights, and marketable pollution allowances. In the context of regulating pollution, there are two types of allowance markets. Tradable *pollution credits* are created when a pollution source reduces its emissions below some individual source-specific target. If pollution regulation caps aggregate rather than individual emissions, then emission permits or allowances take the form of quota shares that are assigned to individual polluters. This latter program is sometimes called a *cap-and-trade* system because it involves the establishment of an aggregate rather than an individual cap on emissions, and tradable allowances take the form of individual quota shares to the aggregate emissions cap. The emphasis in this section of the chapter will be on cap-and-trade systems. Allowance markets are designed to help reduce compliance costs for those firms that are operating under environmental regulations. The cost savings generated by allowances trading will be illustrated by considering pollution allowance trading systems. It is important to recognize that marketable pollution allowance systems do not directly reduce pollution emissions, but are designed to reduce compliance costs in the context of an overall reduction in emissions. The basic structure of a cap-and-trade pollution allowance trading system is as follows:

- Determine an overall maximum level of emissions (the “cap”).
- Assign polluters an individual pollution quota or allowance, usually based on emissions levels in some baseline year; the sum of these allowances is equal to the desired level of emissions.
- Let these allowances be tradable to some degree.
- Require new firms to buy allowances from existing firms.
- Create a *market institution* that minimizes the transaction cost of trades.
- Monitor and enforce sanctions against those that pollute above and beyond their allowance, so firms have an incentive to buy allowances rather than freely pollute.
- Maintain *policy stability* over time so, for example, firms are willing to buy permits knowing that standards will not be lifted in the future.

Now that we see the basic structure, let us look at an illustrative example of how an allowances-trading system can work to reduce the overall cost of attaining a given level of pollution control.

An Illustration of the Cost-Savings Potential from Marketable Pollution Allowances

Consider the highly stylized example in Table 9.2, which features an industry made up of eight polluting firms that have different pollution-abatement costs, but are otherwise identical. Using the data from Table 9.2, we can plot the marginal abatement costs for firms in this industry, as shown in Figure 9.1.

Case 1: Traditional Uniform Performance Standard and No Marketable Allowances

Let us assume that a uniform environmental performance standard of cutting emissions by 50 percent is applied across the firms in this industry based on their historical baseline annual emissions levels. Table 9.3 illustrates the industrywide cost of reducing emissions by 50 percent under this form of regulation.

The total cost of reducing emissions by 50 percent is $6,600 annually when each of the eight firms cuts its emissions by 25 tons.

Case 2: Fully Marketable Allowances

Now consider the same level of pollution control under the condition of marketable allowances. As before, each firm had been emitting 50 tons of

Figure 9.1 Industrywide Marginal Abatement Costs

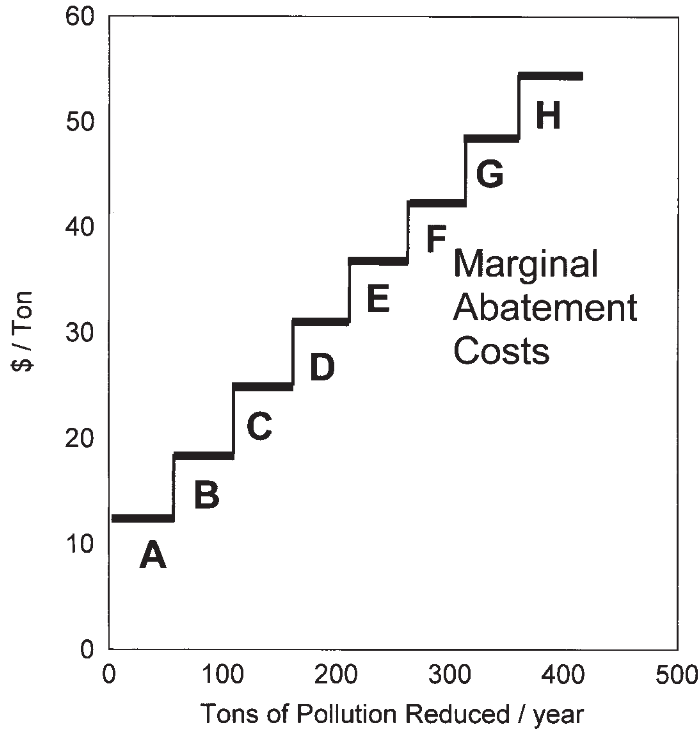


Table 9.2

Hypothetical Example of an Industry with Heterogeneous Marginal Abatement Costs

Firm	Marginal abatement cost	Historical baseline, annual emissions
A	12	50
B	18	50
C	24	50
D	30	50
E	36	50
F	42	50
G	48	50
H	54	50

Note: For analytical simplicity it is assumed that marginal abatement costs are constant, and that historical baseline emission levels are identical across firms. Thus, firms differ only in terms of their marginal abatement costs.

Table 9.3

Hypothetical Industrywide Cost of Cutting Emissions by One-Half Using Traditional Direct Control Regulation

Firm	Marginal abatement cost	Historical baseline, annual emissions	Number of tons of emissions to be reduced	Total abatement cost
A	12	50	25	300
B	18	50	25	450
C	24	50	25	600
D	30	50	25	750
E	36	50	25	900
F	42	50	25	1,050
G	48	50	25	1,200
H	54	50	25	1,350
Total	—	400	200	6,600

pollution each year, and under the regulatory scheme each firm is now only allowed to emit 25 tons per year. Under the new regulatory scheme, the 25 tons per year that firms are allowed to emit are referred to as *allowances*, and these allowances can be traded across the various firms in the industry. Thus, trading rearranges the level of cleanup each firm engages in but keeps the overall level of pollution reduction constant.

To determine the outcome of a marketable allowances regulatory scheme, we first need to predict the *pattern of trade*, meaning which firms will be buyers of allowances (allowing these firms to engage in less cleanup) and which firms will be sellers of allowances (requiring these firms to engage in more cleanup). The answer is that the low-abatement-cost firms (firms A–D) are predicted to *sell* pollution allowances to high-abatement-cost firms (firms E–H). If there were a uniform market price for allowances, what might that price be? A candidate price is $33 per allowance (an allowance is assumed to be for one ton for one year). At $33 per allowance, firms E–H find it cheaper to buy allowances than to cut pollution, and firms A–D find it profitable to sell allowances and engage in additional pollution control at their respective plants. Table 9.4 illustrates how marketable allowance systems reallocate cleanup activity and reduce overall abatement costs.

In this highly simplified example, the total cost of meeting the standard of cutting pollution by half is $4,200, which is somewhat less than two-thirds of the cost of meeting the same overall pollution-control target in the absence of trading. Admittedly, it may be a bit far-fetched to assume that the plants owned by firms A–D can completely eliminate their emissions, but the simple example illustrates the more general concept. Moreover, a bit

Table 9.4

Hypothetical Industrywide Cost of Cutting Emissions by One-Half with Fully Marketable Pollution Allowances

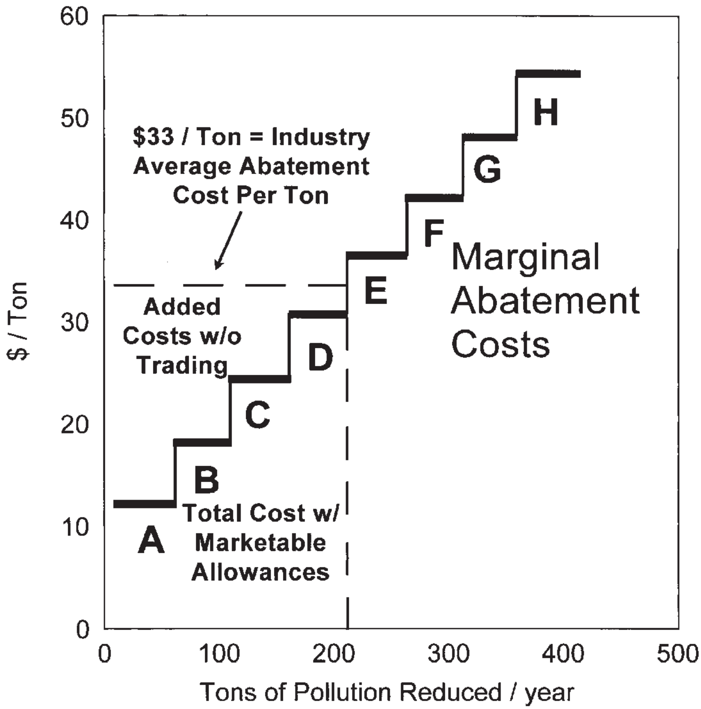
Firm	Marginal abatement cost	Historical baseline, annual emissions	1. Initial tons of emissions to be reduced	2. Allowances sold	3. Allowances bought	4. Final tons of emissions to be reduced (1 + 2 – 3)
A	12	50	25	25	0	50
B	18	50	25	25	0	50
C	24	50	25	25	0	50
D	30	50	25	25	0	50
E	36	50	25	0	25	0
F	42	50	25	0	25	0
G	48	50	25	0	25	0
H	54	50	25	0	25	0
Total	—	400	200	100	100	200

later we will evaluate a more limited allowances-trading system. The remarkable aspect of a marketable allowances system is that it harnesses the cost-minimizing incentives of profit-maximizing firms and the competitive market process to reduce the costs of complying with pollution-control regulations. These cost savings are illustrated in Figure 9.2.

Note that in Figure 9.2 we can use geometry to compare the total cost of cutting emissions by 200 tons per year with and without fully tradable allowances. In the absence of marketable allowances, each ton of sulfur dioxide cleaned up costs society, on average, $33, because each of the eight firms is engaging in an equal amount of pollution abatement, and the average of their marginal abatement costs is $33. Multiplying $33 by 200 tons to be cleaned up yields the total cleanup cost of $6,600 per year. Under a system of fully tradable allowances, however, the four firms with the lowest cleanup costs do all the cleanup in the industry (having sold their allowances to the firms with higher cleanup costs), and so total pollution-abatement costs are represented in Figure 9.2 as the area under the marginal abatement cost function up to the 200 tons of abatement level. The costs saved by the marketable allowances scheme are represented in Figure 9.2 by the difference between $33 per ton and the first four steps on the industry marginal abatement cost function, or $2,400.

More generally, if firms A–H had different upward-sloping marginal abatement cost curves rather than constant marginal abatement costs, then the *equimarginal principle* would operate as a consequence of efficient allow-

Figure 9.2 **Comparison of the Total Cost of Reducing Emissions by One-Half With and Without Fully Tradable Allowances**



ances trading. In particular, suppose that firms A–H each had an upward-sloping marginal abatement cost curve, but with different vertical intercepts. Then at the equilibrium allowance price, the marginal abatement cost of each firm for the last ton cleaned up would be equal to the equilibrium allowance price. As a consequence, the firm with the lowest marginal abatement cost curve would reduce emissions the most, followed by the firm with the next-to-lowest marginal abatement cost curve, and then the next.

Case 3: Limited Allowance Trading

If this is not a perfectly uniformly mixed pollutant, there may be localized “hot spots” near plants that, by buying up allowances, can continue to pollute as before. For example, in July 1997 the group Communities for a Better Environment filed a federal civil rights complaint against the South Coast Air Quality Management District (SCAQMD) and oil companies in the Los

Angeles region, charging that the acquisition of pollution credits from buying and scrapping older, high-polluting cars violates the civil rights of lower-income and minority people who live near the oil refineries. As a consequence, unconstrained trading of allowances may generate an asymmetry in the distribution of emissions that generates greater harms than if emissions reductions were more uniformly applied across the firms. In this case, there is a balancing of cost savings from allowances trading against the need for all sources to limit emissions.

Suppose that we cap trades at 10 tons for each firm. In the example below, we will cap sales as well as purchases, but if dealing with localized hot spots is the concern, it is only necessary to cap purchases by each firm. A cap on both sales and purchases is used here to illustrate the somewhat more realistic case in which all firms clean up to some degree, and yet no firm can completely eliminate its emissions. Table 9.5 shows what will happen under this constrained allowance-trading scheme.

Under this final case, all firms must cut pollution by at least 15 tons per year, which limits localized hot-spot effects. The result, however, of limiting trading is that the cost of meeting the overall standard of cutting pollution by half rises to $5,640, roughly intermediate between the cost with no trading ($6,600) and the cost with unconstrained trading ($4,200). Thus, we can measure the opportunity cost of limiting localized hot spots by the lost cost saving that would have been realized under more complete trading—in this case $5,640 – $4,200 = $1,440.

Advantages of Marketable Allowance Systems

There are both static and dynamic advantages associated with marketable allowance systems. A clear static advantage of marketable allowances is that substantial cost savings are realized from allowing low-abatement-cost firms to sell allowances to high-abatement-cost firms. Consequently, an overall pollution abatement target can be realized at lower total cost when allowances are tradable. Moreover, because firms with high abatement costs are paying someone else to do cleanup for them, this payment becomes a cost and so gives these firms an incentive to find a cheaper way to reduce emissions—R&D. A dynamic advantage of marketable allowance systems is that they give firms an incentive to invest in cleaner technology and cut their emissions below their allowance. The firms can then specialize in selling allowances to those that have not made a similar investment.

Disadvantages of Marketable Allowance Systems

When a firm has *market power*, such as with monopolies or colluding oligopolists, and lower abatement costs than potential entrants, and new en-

Table 9.5

Hypothetical Industrywide Cost of Cutting Emissions by One-Half with Limited Allowances Trading

Firm	Marginal abatement cost	Historical baseline, annual emissions	1. Initial tons of emissions to be reduced	2. Allowances sold (maximum of 10)	3. Allowances bought (maximum of 10)	4. Final tons of emissions to be reduced (1 + 2 – 3)
A	12	50	25	10	0	35
B	18	50	25	10	0	35
C	24	50	25	10	0	35
D	30	50	25	10	0	35
E	36	50	25	0	10	15
F	42	50	25	0	10	15
G	48	50	25	0	10	15
H	54	50	25	0	10	15
Total	—	400	200	40	40	200

trants must buy emissions allowances from the existing firm, then the existing firm can use its dominant position to withhold allowances from potential rivals and so maintain its market power over time (Misiolek and Elder 1989).

Another possible problem occurs when there are few market participants and an ineffective market institution or other barriers to efficient market processes. In this case the *transaction costs* of exchanging emissions allowances may be larger than the value of the allowance itself, in which case allowance market failure results (Foster and Hahn 1995). For example, allowances-tracking systems are necessary so that regulatory agencies know each firm's allowed emissions, and there have been cases in which the cost of registering trades has been so high as to discourage otherwise mutually beneficial allowances transactions.

Policymakers must also be careful to make the allowances short-term in nature so that they do not become a permanent right that could not be adjusted further in the future if new scientific information comes along and policymakers decide to reduce pollution even more. This is part of the reason why the Environmental Protection Agency (EPA) has set the life of an allowance equal to one year.

Finally, as previously mentioned, a problem with unconstrained marketable allowances trading is that it can lead to *hot spots* of localized, high-concentration pollution (known as *concentrated pollution* as opposed to *uniformly mixed pollution*) occurring because the particular firm has bought an extensive number of emissions permits.

Marketable Pollution Allowances and the Clean Air Act (CAA) Amendments of 1990: The Acid Rain Program

Acid deposition occurs as a by-product of burning fossil fuels. Sulfur dioxide (SO_2) and nitrogen oxide emissions react with water droplets, oxygen, and various oxidants in the atmosphere, usually in cloud layers, to form solutions of sulfuric and nitric acid. These reactions are hastened by sunlight. Rainwater, snow, fog, and other forms of precipitation containing those mild solutions of sulfuric and nitric acids then fall to Earth as acid rain. Interestingly, about half the acidity created through such atmospheric reactions falls to Earth's surface in the form of dry depositions, which are then blown by the wind or washed into waterways by subsequent rainfalls. According to the National Acid Precipitation Assessment Program, normal rainfall has a pH of 6; however, acidification of rain has lowered this pH in many areas of the northeastern United States and southeastern Canada to values ranging from 4.2 to 4.4, approaching the pH levels in cola soft drinks. This reduction in pH values of the soil and water bodies that absorb it results in damage, or in extreme cases, sterility to the associated terrestrial or aquatic ecosystems.

In addition to the northeastern United States and southeastern Canada, other primary deposition areas are associated with intense burning of fossil fuels in northern Europe and parts of East Asia. Terrestrial ecosystems particularly damaged by acid rain occur at high altitudes, as in the Appalachian and Adirondack Mountains of the eastern United States, where acid rains and fogs frequently bathe and envelop the forests, meadows, streams, and lakes of the area, and have made many of these waters uninhabitable to native fish and other aquatic life.

In the United States, about 75 percent of the emissions of sulfur oxides are generated by electric utility power plants that burn fossil fuels, especially high-sulfur coal, and are particularly concentrated in the Midwest. Generation of the other major source of acid rain, emissions of nitrogen oxides, is somewhat more equally distributed between motor vehicles and electric utilities. Acids can remain in the atmosphere for weeks at a time and be transported by prevailing winds for hundreds of miles before they are deposited. In 1984, the U.S. Office of Technology Assessment estimated that in addition to the environmental damage caused by acid rain, acidic aerosols—small water droplets containing compounds of sulfur, nitrogen, and chlorine—may be responsible for as many as 50,000 deaths in the United States each year, and pose a serious threat to people with respiratory illnesses.

When the U.S. Congress amended the Clean Air Act in 1990, the amendments included an experiment with the use of markets in reducing the cost of meeting sulfur dioxide emissions reductions. Title IV of the Clean Air Act addresses the control of acid rain and sets the overall goal of reducing annual SO_2 emissions by 10 million tons below 1980 levels. These reductions are to be achieved through a two-phase process that will place increasingly tight restrictions on the emissions of coal and other fossil-fuel-powered utilities. Information on the EPA's Acid Rain Program, some of which is summarized below, can be found on the World Wide Web at http://www.epa.gov/docs/acidrain/ardhome.html.

The first phase of the Acid Rain Program began in 1995 and affects a total of 445 coal-burning electricity units located in 21 eastern and midwestern states. Interestingly, preliminary data reported by the EPA indicate that 1995 SO_2 emissions at these units were reduced by almost 40 percent below their required level. The second phase, which began in 2000, extends restrictions to many smaller, cleaner plants and imposes a further tightening of the phase 1 standards on the larger and dirtier plants. The program affects existing utility plants having generators with an output capacity of greater than 25 megawatts as well as all newly built plants. The Clean Air Act requires that by 2010, the scope of the Acid Rain Program be broadened to include more than 1,000 U.S. electricity-generating facilities. The Clean Air Act also addresses emissions of nitrogen oxides, and requires a total reduction of 2 million tons relative to 1980 levels by 2000. The EPA claims that a significant portion of this reduction will be achieved by coal-fired utility boilers that will be required to install new burner technologies.

Under the trading system devised by the EPA, affected utility plants are allocated allowances based on their historic fuel consumption and emissions rate. Each allowance permits a plant to emit a ton of SO_2 during or after a specified year. Once a ton of sulfur dioxide is emitted in a particular year, the allowance is "retired" and can no longer be used. These allowances may be bought, sold, or banked. Any person may acquire allowances and participate in the trading system. The EPA must be able to keep track of the ownership of allowances to determine whether a plant has exceeded its allowed emissions. The EPA does so through the Allowance Tracking System, which monitors the transfer of ownership of allowances. Finally, regardless of the number of allowances a utility holds, the plant may not emit at levels that would violate federal or state limits set under Title I of the Clean Air Act to protect public health. This is a cap-and-trade regulatory system because the Acid Rain Program regulates overall emissions, and tradable allowances are quota shares.

As of December 31, 1999, the Allowance Tracking System had recorded more than 9,300 allowance transactions involving the transfer of more than 81.5 million allowances, approximately 62 percent of which were transferred across units within a given firm. The remaining 31 million allowances were transferred across firms. The most common type of transfer across firms is between an allowance broker and a public utility. Fuel suppliers such as Peabody Coal can purchase allowances through private transfer or the EPA auction, bundle the allowances with coal or other fuel that they sell that generates SO_2, and then sell the fuel bundle to utilities.

However, not all transfers are cash transactions. For example, in October 1995, Allegheny Power traded 20,200 1996 and 1997 allowances to Duke Power Company in return for 20,000 1995 allowances. One place where allowances prices are generated is the EPA allowances auctions. In the 1996 EPA auction, slightly more than 85 percent of the allowances were bought by brokerages and other intermediaries such as Enron Power Marketing (71.5 percent), AIG Trading Corporation (7.7 percent), and Cantor Fitzgerald Brokerage (6.5 percent), which then bundled them for resale or some other form of private transfer to various public utilities. More recently, public utilities such as Pacific Gas and Electric have played a more dominant role as buyers in the EPA auction. Preliminary information from the EPA indicates that SO_2 emissions declined by 700,000 tons during 1999 as companies prepared to meet their Phase II reduction obligations. Because SO_2 emissions have dropped so much already, and over 11 million allowances have been banked, the EPA expects to see only gradual reductions in SO_2 between 2000 and 2010 as the Acid Rain Program moves toward the full 10 million ton reduction mandated by the Clean Air Act.

An interesting phenomenon in allowance trading is the rise of groups that purchase allowances and simply retire them as a market-oriented strategy for cleaning the environment. For example, in the 2000 spot auction (allowances purchased for use in 2000), the Acid Rain Retirement Fund purchased 13 allowances, the Maryland Environmental Law Society purchased 10, and the Isaac Walton League, VA/Clean Air Conservancy purchased 5 allowances. Other groups purchased smaller quantities. Environmental groups have purchased and retired SO_2 allowances every year since the EPA auction has been conducted. One of the largest such purchases was by the National Healthy Air License Exchange and the Glens Falls, New York, middle school, which raised over $20,000 to purchase and retire nearly 300 tons of SO_2.

In 1994, the price of an allowance was approximately $150. By 1996, the price of an allowance had fallen to about $65, though by the end of the year prices had recovered to almost $100. By February 1999, the price of an allowance peaked at approximately $210, and later fell back to about $140 by February 2000. It is interesting to note that the price of allowances is substantially below the levels anticipated when the program was established in 1990. In particular, some observers originally anticipated that allowance prices would be about $850, and the EPA originally estimated that allowances would trade at approximately $750.These low allowance prices have resulted in a substantial cost savings for the SO_2 reduction target.

In his survey of the literature on the cost of complying with the Acid Rain Program, Burtraw (1998) compared early and more recent studies to show how implementation has affected cost estimates. Early studies estimated annual compliance costs of between $2 billion to $5 billion (1995 dollars), whereas more recent studies that have taken into account the actual performance of the Acid Rain Program estimate annual compliance costs of approximately $1 billion (1995 dollars). Carlson et al. (1998) attribute annual cost savings of approximately $780 million due to allowance trading, which represents an estimated 42 percent savings relative to command-and-control projections.

One concern regarding allowance trading is the potential for creating localized hot spots. Swift (2000) has found that, in fact, the largest coal-burning plants, with the largest SO_2 emissions, reduced their emissions by the largest percentage under the Acid Rain Program. These firms are able to spread pollution abatement costs over a larger dollar value of capital. Consequently, Swift argues that the data allay concerns about localized hot spots under the Acid Rain Program. There have been some problems with implementation of the Acid Rain Program. For example, McCormack and Shaw (1996) report that the New York legislature tried to ban interstate allowances trades on the grounds that an electricity generator in New York might profit from selling allowances to generators in the midwestern United States, and with the prevailing wind pattern, increased midwestern emissions would result in increased acid rain deposition in New York.

Regional Clean Air Incentive Market

In October 1993, California's South Coast Air Quality Management District initiated a new cap-and-trade regulatory system for controlling emissions of oxides of sulfur and nitrogen, called the Regional Clean Air Incentive Market (RECLAIM), a prominent element of which features the trading of pollution allowances on the Internet. As of 1996, the RECLAIM Automated Credit Exchange (ACE) was the only electronic, interactive emissions market, one that enables participants to view price revisions through several rounds of bidding prior to actual trading. The preliminary bidding rounds allow prices to stabilize prior to trading. The ACE also allows for trading of "package orders," bundles of different types of RECLAIM Trading Credits (RTCs) over multiyear periods. More than 15 million RTCs were traded in 1996. Anderson (1997) predicted that this cap-and-trade system would reduce compliance costs by 42 percent, the same percentage cost savings estimated for the Acid Rain Program allowance market.

Emissions Trading

So far we have focused on cap-and-trade systems. Let us now consider a tradable pollution credit system in which individual credits are created when a polluter reduces emissions below the maximum level allowed by law. The various EPA emission-trading programs have existed since the mid-1970s. These are regional, state-controlled programs designed and operated in co-operation with the EPA. Hahn (1989) estimates that cumulative cost savings created by the various emissions-trading programs range from $500 million to $12 billion. Target pollutants include volatile organic compounds, carbon monoxide, sulfur dioxide, particulates, and nitrogen oxide. Emission Reduction Credits (ERCs) are earned whenever a polluter reduces emissions below the level required by law. The ERCs are usually earned from exceeding compliance standards (usually resulting from either the installation of a new production process or a plant that closes down). An ERC gives the owner the right to emit a ton per year of the stated pollutant while the ERC is valid. The ERCs can be transferred within a multiplant firm or by way of "external trading." In highly impacted nonattainment areas (like Los Angeles), companies must acquire more than one ERC for every unit of emissions (typically 1.2 ERCs bought for every ton of pollution) so that overall emissions are reduced. The ERCs can then be traded in a number of ways.

First, ERCs can be used to *offset* new facilities (and their emissions) locating in "nonattainment areas" that have not met a specified ambient air quality standard. The CAA specified that no new emissions sources would be allowed to locate in nonattainment areas after 1975. Concern that the prohibition would stifle economic activity led the EPA to develop offset ERCs. An "offset" is a type of ERC specifically designed for new factories or other new sources of pollution to be built in areas that exceed emissions standards. Offsets can be traded internally within a multiplant firm or via external trading.

Another way that ERCs are traded is in a process called *netting.* Netting allows a firm that creates new sources of emissions in a plant to avoid the stringent emissions limits that would normally apply by reducing emissions from another source in the same plant. A firm using netting is allowed to obtain the necessary ERCs only from its own sources (internal trading).

Yet another way that ERCs can be traded is by way of trades within a given *bubble.* The bubble program is similar to the offsets program but applies to ERC trades involving existing factories rather than newly constructed ones. The term *bubble* refers to placing an imaginary bubble over a given plant, with all emissions exiting from a single outlet to the bubble. Thus, bubbles allow a company to sum its total plant emissions and adjust individual sources of pollution within the plant so that the aggregate limit is not exceeded. This part of the program began in 1979. Bubble credit transfers have not generated a lot of transactions, some say because of regulator opposition, the nonuniform mixing nature of the pollutants, and thin regional markets, among others.

Finally, ERCs (unlike allowances in the Acid Rain Program) can be *banked* for future sale or use. States decide the specific rules and administer ERC banking. Foster and Hahn (1995) find that banking acts reduce the *transaction costs* of ERC trading significantly, especially for small-scale trades.

Other Experiments with Marketable Allowances

Fox River oxygen trading: Under this Wisconsin program, pulp paper mills and sewage treatment plants were required to purchase oxygen depletion allowances (see O'Neil et al. 1983).

Lead banking: In this pollution credit trading program, refiners were allowed to bank and trade lead allowances to meet a short-timeline phaseout of leaded gasoline in a more cost-effective manner. Refiners that reduced lead content below the standard requirement received credits that could be "banked" and used in the future. Half of all refiners participated, 15 percent of allowances were traded, and 35 percent of production rights were banked. Hahn (1989) estimated $228 million in cost savings.

Chlorofluorocarbon (CFC) trading: As discussed in chapter 7, the Montreal Protocol was an international environmental agreement in which signatory countries agreed to a 1998 CFC cap equal to 50 percent of 1986 levels. Developed countries such as the United States later agreed to a complete phaseout of production. During the phaseout period, the USEPA instituted a cap-and-trade system for the phaseout of CFCs. It is estimated to have saved several billion dollars in compliance costs. Similar production quotas were utilized in Canada, the European Union, and Singapore (Stavins 2000).

Heavy-duty motor vehicle engine emissions trading system: Engine manufacturers that produce heavy-duty engines that emit less nitrogen oxide than is required by law are granted credits that can be used to offset engines that fail to meet the standard. These credits can be used by the firm that produced them or traded to other firms. Credits can also be banked for future use.

Joint implementation of greenhouse gas controls: Countries that had ratified the Framework Convention on Climate Change established a joint implementation program in the 1995 Berlin Conference of the Parties. The 1997 Kyoto Protocol allows Annex B countries (countries that have an agreed ceiling on emissions) to meet their ceiling by way of emissions trading with other Annex B countries, and through joint implementation programs. In the pilot joint implementation program, Annex B countries finance projects in other countries that reduce emissions of greenhouse gases, and these emission reductions are then credited toward meeting the Annex B country's ceiling. The U.S. Initiative on Joint Implementation has approved 22 such projects through 1997, and the worldwide total through 1999 was 94 (Stavins 2000). Most of these projects have funded the transition to less polluting energy production processes or have focused on land use in Latin America and other lower-income countries.

Transferable development rights (TDRs): As Convery (1998) observes, jurisdictions use transferable development rights in environmentally sensitive or unique areas where development should be limited or prohibited. Landowners in these "sending areas" are given development units that can only be exercised in a less sensitive "receiving area" such as within an urban boundary, and developers in the receiving area wishing to exceed density restrictions can purchase these rights. For example, Washington's Clallam County has an ordinance that transfers development rights from agricultural land to receiving areas in the Sequim Urban Growth Area. Likewise, Seattle residential properties occupied primarily by households with annual incomes at or below 50 percent of median income, and structures designated as Seattle landmarks by Seattle's Landmarks Preservation Board, became "Sending Sites" eligible to sell TDRs to office, hotel, and retail "Receiving Sites."

Environmental Taxes

Recall from chapter 4 that environmental taxes, such as those charged to polluters, are another form of incentive regulation in which something bad (pollution) is taxed in order to provide an incentive for it to be reduced. Pigouvian taxes are a particular form of pollution tax that is designed to internalize external costs, but given the difficulties in precisely measuring external costs and the vagaries of the political process, most pollution taxes are not designed to internalize external costs perfectly. Pollution taxes can take the form of a per-unit (excise) tax on inputs such as coal or outputs such as electricity that generate pollution. When monitoring data permit, pollution taxes and charges can be directly assessed on pollution emissions themselves (these are sometimes called *effluent taxes*). A negative environmental tax is a tax credit that subsidizes environmentally friendlier goods and services. For example, the Energy Policy Act of 1992 provides a 1.5 cent per kilowatt-hour credit for energy generated from wind or biomass sources, and solar and geothermal energy projects can receive up to a 10 percent tax credit. As Barthold (1994) points out, systems of taxation for a long time have had consequences for environmental quality, though those consequences have often been unintended. The oil crisis of 1973–74 led to some of the first tax policies designed with the purpose of promoting energy conservation and use of alternative energy. In 1978, for example, the U.S. Congress passed the gas-guzzler tax, an excise tax that varies inversely with the EPA's fuel economy rating of automobiles.

Environmental Taxes in the United States

A selected listing of federal taxes that act either directly or indirectly as environmental taxes is given below:

- *Superfund:* Enacted in 1980, it charges a tax of $0.097 per barrel of crude oil, $0.22 to $4.87 per ton of chemicals, and 0.12 percent on elements of corporate taxes, with the funds entirely dedicated to hazardous substances cleanup.
- *Oil spill:* Enacted in 1989, it charges a tax of $0.05 per barrel of crude oil, with the funds entirely dedicated to the Oil Spill Liability Trust Fund (maximum $1 billion reserve).
- *LUST*: Enacted in 1986, this rule taxed all nonpropane fuels at the rate of $0.001 per gallon to remediate leaking underground storage tanks. The LUST tax expired at the end of 1995.
- *Noncommercial motorboat fuels:* Enacted in 1932 and modified several times since, the environmental element of this rule taxes gasoline at $0.183 per gallon, with $0.14 of the $0.183 dedicated to the Aquatic Resources Trust Fund.
- *Ozone-depleting chemicals:* As CFC production was being phased out in the United States, there was concern that declining production quotas combined with persistently high demand would result in excessive profits earned by Du Pont and other CFC producers. These excess profits could, however, be transferred to the public by way of a tax. Enacted in 1986, the tax rate per pound of ozone-depleting chemical was equal to an escalating base rate multiplied by the chemical's estimated "ozone-depleting potential" (ODP). The base rate started at $1.37, rising to $3.10 by 1995 (after which the U.S. production ban took effect). The baseline ODP was set at 1.0 for CFC-11, and the ODP for other chemicals was related to that of the baseline. For example, halon H-1301 has an ODP of 10, meaning that a pound of H-1301 has ten times the ozone-depleting potential of CFC-11, while "transitional" CFC substitute HCFC-22 has an ODP of 0.05, and CFC substitute HFC-125 has an ODP of 0.0.
- *Firearms and ammunition:* Enacted in 1918, this rule taxes firearms and ammunition at the rate of 10–11 percent, with the proceeds dedicated to the Federal Aid to Wildlife Program.

- *Wind production tax credit:* Enacted in 1992, this rule grants a tax credit of \$0.015 per kilowatt-hour of electricity produced using wind, credited against income tax. (Adapted from Barthold 1994, pp. 146–50).

Environmental Taxes Around the World

So far we have focused on market-based regulatory systems in the United States, but various systems are in place around the world. The Organization for Economic Cooperation and Development (OECD, 1997) provides a comprehensive list of environmental taxes in OECD countries (OECD members include the United States, Canada, Mexico, Australia, New Zealand, Japan, Republic of Korea, Turkey, Greece, and many European countries). For example, most OECD countries that still allow lead in gasoline also impose a differential environmental tax on lead that favors the use of unleaded gasoline. Denmark, Finland, the Netherlands, Norway, and Sweden impose an environmental tax on energy based on carbon emissions. Belgium, Denmark, France, Japan, Norway, Poland, and Sweden all have developed environmental charges on energy based on sulfur emissions. The Czech Republic, France, Poland, and Sweden impose a nitrogen oxide charge on energy. Eleven of the 28 OECD countries utilize water effluent charges and impose noise charges on aircraft. France taxes water pollution and reinvests the revenues in pollution remediation, and Poland's stringent effluent fees include a penalty for emissions that exceed the regulatory standard. Belgium taxes disposable razors and cameras, Sweden taxes the production of various chemicals and uses the proceeds to fund monitoring and enforcement, and Iceland levies a differential import levy to promote smaller and more fuel-efficient automobiles. Mexico has reduced taxes on new cars and increased them on older "dirtier" cars to limit air pollution, and Argentina and Columbia offer subsidies for industrial pollution abatement investments, and tax rebates for those who adopt cleaner technology. Chile has developed a tradable permit system for particulate matter from stationary sources in the Santiago area, and Singapore has had a tradable permit system for ozone-depleting chemicals since 1991 (Stavins 2000).

Simulation Research on the Effects of Taxing Carbon Dioxide Emissions

As we shall discuss in greater detail in chapter 10, carbon dioxide is a greenhouse gas and thus may contribute to global warming. A number of studies have attempted to model the effects of pollution taxes on carbon dioxide. One approach, taken by the Center for Global Change at the University of Mary-

Table 9.6

Simulation Effects of a $7.50 Per Ton Tax on Carbon Equivalent Emissions for the State of Maryland, 1993

Fuel/energy source	Tax rate Implied by a $7.50/ton tax on carbon equivalent emissions	Annual state revenues generated by fuel type in millions of dollars (percentages of total in parentheses)	
Coal	$5.26 per ton	3.9	(2)
Fuel oil	2.3 cents per gallon	*	
Residual oil	$1.11 per barrel	*	
Gasoline	2 cents per gallon	41.1	(23)
Natural gas	1.3 cents per therm	21	(12)
Electricity	0.16 cents per kwh	83.6	(47)
Other oil products	—	29.8	(17)

Source: The State Carbon Tax Model of the Center for Global Change, University of Maryland. The Center grants permission to reproduce, modify or use the State Carbon Tax Model and User's Guide provided that analysis based on the model credits "The State Carbon Tax Model of the Center for Global Change, University of Maryland," and that this permission notice is included in any copy.

*These are elements of the "other" category.

land, is to evaluate the effects of carbon taxes on the price of various carbon-emitting fossil fuels, and the fiscal effects on state budgets. Consider the example in Table 9.6 from the center's Carbon Tax Model for the State of Maryland.

The Carbon Tax Model for the State of Maryland also indicates that a $7.50 per ton tax on carbon-equivalent emissions would on average increase a household's expenditures on energy by about $45 per year, roughly equally divided between residential energy and gasoline.

Summary

- *Incentive regulation* refers to economic instruments such as cap-and-trade systems or environmental taxes that foster more environmentally friendly behavior and reduce compliance costs. Incentive regulation frequently operates indirectly by changing the incentives of firms, consumers, and government in a way that promotes the environment and public health.
- *Command-and-control regulation* specifies how pollution is to be reduced through the application of uniform standards for firms, most prominently technology-based ("technology-forcing") or performance-based standards.

- *Technology-based standards* specify the specific methods and equipment that companies must use to comply with environmental regulation.
- *Performance-based standards* set uniform control targets for all regulated firms, but unlike technology-based standards, companies are given some choice over how the target is actually met (Stavins 2000).
- The original Clean Air Act of 1970 includes elements of command-and-control regulation. The Clean Air Act required that costly scrubbers be installed on coal-burning electricity-generating facilities, even though many could have generated the same cleanup by shifting to less expensive low-sulfur coal.
- *Marketable pollution allowances* are one form of incentive regulation. Marketable pollution allowances reduce compliance costs when polluters have different marginal abatement costs. Regulators give firms a reduced level of emissions as an "allowance" or permit and then grant companies the right to trade some or all of that allowance to other companies.
- The cost savings result when firms with high abatement costs purchase allowances from firms with low abatement costs, meaning that firms with low abatement costs subcontract to do some of the cleanup for the high-abatement-cost firms.
- In order for markets for pollution allowances to function, regulators must monitor and enforce the allowances so that firms cannot simply exceed allowed emissions, which would eliminate the incentive to purchase allowances.
- Tradable *pollution credits* are created when a pollution source reduces its emissions below some individual source-specific target. If pollution regulation caps aggregate rather than individual emissions, then emission permits or allowances take the form of quota shares that are assigned to individual polluters. This latter program is sometimes called a *cap-and-trade* system because it involves the establishment of an aggregate rather than an individual cap on emissions, and tradable allowances take the form of individual quota shares to the aggregate emissions cap.
- A prominent example of a cap-and-trade system is the EPA's Acid Rain Program, in which sulfur dioxide allowances are traded on the Chicago Board of Trade, and allowance prices are much lower than had originally been anticipated.
- One potential limiting factor for marketable allowances is the problem of localized "hot spots," which can occur when a firm buys so many allowances that it does not have to clean up at all (other firms have subcontracted for the cleanup). If the pollutant is not uniformly mixable in the atmosphere, then there could be substantial localized impact from this outcome. As a result, regulators may limit marketable allowance

schemes to require all firms to clean up some minimum amount. While these restrictions limit the cost-savings potential, they can prevent localized hot spots from developing.

- Another form of incentive regulation is pollution taxes, also known as *environmental excise taxes.* A.C. Pigou and other economists have long argued for environmental taxes as a way to cause companies to internalize external costs and cause consumers to be confronted with prices that reflect the full marginal social cost of production. The incentive effect of pollution taxes is that they create a new cost that profit-maximizing firms then have an incentive to minimize. For example, pollution taxes make environmentally friendly technology more attractive and thus promote R&D and adoption of these technologies as a way to avoid the excise tax.
- Environmental taxes can be charged on polluting inputs such as coal, on goods and services such as electricity, or directly on pollution emissions. Direct taxes on pollution emissions are sometimes called *effluent taxes* or *charges*. The gas guzzler tax and the tax on production of CFCs are examples of U.S. environmental taxes. Various environmental taxes have been used worldwide.

Review Questions and Problems

1. Go back to the tables in the chapter for the illustration of the cost savings from marketable allowances.
   a. Redo the illustrative example of the cost savings from fully marketable pollution allowances relative to command-and-control regulation (case 2), assuming that emissions will be cut by 60 percent rather than 50 percent. Calculate the cost savings from fully marketable allowances relative to traditional command-and-control regulation. Assume that a firm cannot clean up beyond its historical baseline emissions level.
   b. Independently of your work in part (a) above, redo the illustrative example of the cost savings from constrained allowances trading in the text (case 3) but now impose a constraint that no more than 15 tons of emissions can be bought or sold by a particular firm as a means of reducing the creation of localized hot spots of pollution. Calculate the total cleanup cost relative to unconstrained market trading and traditional command-and-control regulation. What is the opportunity cost of imposing the 15-ton trading constraint to limit localized hot spots relative to unconstrained market trading?
2. One of the criticisms of using indirect controls such as pollution taxes to limit pollution is that firms will simply view the taxes as a part of the cost

of doing business and pass these taxes along to their consumers while continuing to pollute as before.

a. Explain the relationship between the size of marginal abatement costs and the pollution tax that is implied by the above statement.
b. Describe the shape of the market demand curve implied by the above statement. For what industries might this condition come closest to coming true?
c. Might the shape of the demand curve for the industries you described above change over time if a pollution tax is imposed? If so, why? *Hint:* Consider the dynamic incentives for developing substitutes.

3. Draw a diagram in which firms A–H each have upward-sloping marginal abatement cost functions. Draw a uniform price for allowances such that the amount of abatement by each firm sums to exactly one-half of the firm's historical emissions level. (*Hint:* The length of each firm's marginal abatement cost curve on the "x" axis should be its historical emissions level.)

a. Indicate on your diagram how much pollution abatement each firm will perform in equilibrium after complete market trading.
b. Explain why the equimarginal principle results in cost-minimizing pollution abatement.

4. Download information on the volume of trade and allowance prices from the EPA's Acid Rain Program Web page: (http://www.epa.gov/docs/acidrain/ ardhome.html). How have allowance prices and the volume of trade changed from the numbers given in the chapter? What are the factors that led to the changes you have identified?

5. Access the Resources for the Future *Discussion Paper* 00–09 by Robert Stavins, which reviews the use of economic-incentive or market-based environmental policy instruments around the world (http://www.rff.org/disc_papers/abstracts/0009.htm). Note that the full paper is a PDF file that requires the free Adobe Acrobat program. Summarize the workings of an incentive-based environmental policy instrument used outside of the United States.

Internet Links

Acid Rain Program (http://www.epa.gov/docs/acidrain/ardhome.html): Read about the trading of sulfur dioxide allowances at this EPA site.

Citizen's Guide to Environmental Tax Shifting (http://www.foe.org/envirotax/taxbooklet/): A site produced by Friends of the Earth that is dedicated to shifting taxes from "goods" to "bads." Chapter 3 of this tax booklet describes some actual examples of environmental tax shifting, particularly in Sweden.

Cost Savings, Market Performance, and Economic Benefits of the U.S. Acid Rain Program (http://www.rff.org/disc_papers/abstracts/9828.htm): Resources for the Future *Discussion Paper* by Dallas Burtraw.

Economic Savings from Using Economic Incentives for Environmental Protection (http://199.223.18.220/ee/epa/incsave.nsf): This comprehensive 1999 survey by Robert Anderson describes the cost savings generated by various federal environmental programs that utilize economic incentives.

Environmental Policy Implementation in the Netherlands (http://www.rri.org/envatlas/europe/netherlands/nl-inst.html): Read about the economic instruments used in the Netherlands to control pollution and improve the environment. Produced by the Resource Renewal Institute.

Experience with Market-Based Environmental Policy Instruments (http://www.rff.org/disc_papers/abstracts/0009.htm): Resources for the Future *Discussion Paper* 00–09 by Robert Stavins reviews the use of economic-incentive or market-based environmental policy instruments worldwide.

Harnessing the Tax Code for Environmental Protection: A Survey of Initiatives (http://www.sustainableeconomy.org/): An accessible and comprehensive study by J. Andrew Hoerner of the Center for a Sustainable Economy; it describes the rationale for environmental taxation and identifies 462 environmentally motivated state-level tax provisions.

Interactive Marketable Pollution Allowances Simulation (ftp://sorrel.humboldt.edu/pub/envecon/module4.xls): A simple and informative interactive simulation produced by textbook author Steven Hackett that operates on an Excel platform. The user does not need to know anything about Excel to use the simulation. Be sure to enable macros when asked.

Pollution Allowances Audio Clip (http://www.humboldt.edu/~envecon/audio/3.ram): Audio clip provided by textbook author Steven Hackett on tradable pollution allowances.

State-Level Environmental Taxes (http://www.cfpa.org/issues/environment/etax/etmodleg.cfm): Read about various state environmental taxes and model legislation.

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10

Global Climate Change: Uncertainty, Irreversibility, and Long-Term Policy-Making

Introduction

There is an emerging scientific consensus regarding the relationship between the emission of certain gases due to human activity, and observed changes in the global climate. Various different *greenhouse gases* in the atmosphere allow visible light to pass through but block much of the heat reflected from Earth's surface. Without this greenhouse effect, Earth's mean surface temperature would be about 33°C lower than it is today, most of the world's oceans would freeze over, and life on the planet would obviously be fundamentally altered. Aside from water vapor, greenhouse gases include (with their relative contribution to global warming, using National Aeronautics and Space Administration [NASA] and IPCC 1992 assessment data, in parentheses):

- Carbon dioxide (CO_2: 56 percent), produced during the burning of fossil fuels
- Nitrous oxide (N_2O: 7 percent), produced during the burning of fossil fuels
- Methane (14 percent), produced by the breakdown of plant materials by bacteria, such as in the stomachs of ruminant livestock
- Halocarbons (23 percent), prominent among them being chlorofluorocarbons, manufactured for coolant and other industrial and commercial applications.

These gases trap heat reflected from Earth, like the windows in a greenhouse, causing global warming. Some carbon dioxide and methane are generated by nonhuman sources such as wildlife, swamps, volcanoes, and bogs, but human activities have boosted their levels in the atmosphere, as described below. Rising greenhouse gas emissions are inextricably linked to industrialization and the way of life of our growing human population. Climate change models indicate that this *greenhouse effect* is enhanced as concentrations of these gases increase in the atmosphere. Scientists are refining global climate change models, but the feedback effects are very complex, and considerable uncertainty remains regarding future impacts on weather, ecosystems, and human health.

The Intergovernmental Panel on Climate Change (IPCC), established in 1988 by the World Meteorological Organization and the United Nations Environment Program, is a primary source of information on global climate change. The IPCC is made up of scientists and technical experts from government, academia, and the private sector worldwide, and is designed to offer a reasonable gauge of the consensus view held by the scientific community on global warming. Despite the high degree of complexity and uncertainty associated with the mechanics of global warming, the IPCC stated in 1995 that the climate data are consistent with discernible human-induced (anthropogenic) heating caused by greenhouse gas emissions. The high degree of complexity and uncertainty has been exploited to varying degrees by members of the fossil-fuel industry to stymie efforts at reducing greenhouse gas emissions. Yet if the predictions of the climate change models come true, there will be large-scale changes in the global climate that are effectively irreversible from the perspective of a human lifetime, affecting agriculture, ecological and hydrological systems, and human health and safety.

As a consequence, global climate change exemplifies a global environmental policy dilemma:

- Today's costs of making a substantial reduction in greenhouse gas emissions are large in absolute amount and are concentrated on fossil-fuel industries and their consumers.
- The estimated benefits of substantially reducing greenhouse gas emissions are diffuse across the globe, uncertain or unknown in terms of probability and magnitude, and primarily fall in the future. Moreover, global warming has the characteristic of irreversibility from the perspective of the next few human generations; Maier-Reimer and Hasselman (1987) estimate that it will take approximately 1,000 years to remove 85 percent of the excess carbon dioxide from the atmosphere.
- With costs concentrated and in the present, and with benefits diffuse,

uncertain, and cast in the future, the political economy of greenhouse gas control is "Olsonian" in the sense that this term is used in chapter 7. Therefore, coordinated international policies to slow or reverse global climate change will tend to be difficult to achieve and unstable.

- For global-warming policy to be effective, there must be international coordination and cooperation across countries that are highly diverse in income, religion, culture, population growth rates and other demographic characteristics, educational attainment, and extent of democratic empowerment. The process creates an incentive for countries to free-ride on the greenhouse gas-control efforts of other countries.

These factors make global climate change one of the greatest environmental policy challenges confronting people today.

This chapter begins by summarizing scientific predictions for future greenhouse gas emissions; it then reviews global climate change scenarios predicted as a consequence of greenhouse gas emissions. Next, we will survey the scientific evidence for human-caused global climate change and then consider the record of international action on the problem of global climate change. A number of economic policy studies have estimated costs and benefits associated with the control of greenhouse gases, and after reviewing international action on global climate change, we will examine several economic studies of greenhouse gas control. An important element of greenhouse gas control is the ability of developing countries to "leap-frog" from a less-industrialized status to sophisticated climate-friendly technologies. The chapter concludes with a discussion of climate-friendly technology transfer and the Clean Development Mechanism of the Kyoto Protocol.

Predictions Regarding Greenhouse Gas Emissions and Global Climate Change

Predictions Regarding Greenhouse Gas Emissions

Human activity has increased concentrations of carbon dioxide in the atmosphere. Baseline concentrations of carbon dioxide going back 1,000 years and more are about 280 parts per million (ppm). Starting around the 1780s—the beginning of the Industrial Revolution and the rapid rise in human population—atmospheric concentrations of carbon dioxide began rising, and they are now approximately 360 ppm. Global anthropogenic carbon dioxide emissions are about 6 billion tons per year. As we have seen in the preceding section, however, carbon dioxide is not the only greenhouse gas, and recent forecasting work by the IPCC includes a comprehensive look at emissions of all the greenhouse gases as well as gases that interact in some way with greenhouse gases. Estimates of greenhouse gas concentrations by the year 2100 depend on the complex interaction of a number of factors. These include (1) human population levels, growth rates, and demographic composition; (2) the degree of reliance on various fossil-fuel energy sources and the extent of sulfur dioxide emissions; (3) the degree of deforestation and other relevant land-use decisions; (4) technological innovation and resource efficiency; and (5) the growth of the world's economies. The future evolution of these factors is highly uncertain. The IPCC (2000) has issued a set of scenarios for greenhouse gas emissions by 2100. By then, the world will have changed in ways that are as difficult for us to conceive of today as it was for people in 1900 to envision the world in 2001 and beyond. Scenarios are alternative images of how the future might unfold. The IPCC predictions begin with narrative storylines, each of which is based on a different set of assumptions about trends in the above-named factors. Each storyline assumes a distinctly different direction for future developments, and so the storylines differ in increasingly divergent and irreversible ways. Several different modeling scenarios were then developed for each storyline to examine a range of possible emissions outcomes. All the scenarios that are based on a particular storyline constitute a scenario family. The IPCC considers all storylines and scenarios to be equally valid, and it does not assign probabilities to various storylines or scenarios.

As described by the IPCC (2000), the A1 storyline considers a future world of rapid economic growth. Global population will have peaked at 8.7 billion by 2050 and will decline to 7 billion by 2100. There will be rapid development and diffusion of new and more efficient technologies. There will be a global convergence in standards of living, per capita income, and fertility, increased capacity-building, and increased cultural and social interaction. The A1 scenario family has three members. The A1FI scenario assumes continued use of fossil fuels, A1T assumes transition to nonfossil fuels, and A1B assumes a balanced use of fossil and nonfossil fuels. The A2 storyline and scenario family describe a heterogeneous world with underlying themes of self-reliance and preservation of local identities. Fertility patterns across regions converge relatively slowly, causing population to continuously rise from current levels to 15 billion in 2100. Economic development is regional in focus, and both per capita economic growth and technological innovation are relatively more fragmented and slower than in the other storylines. The B1 storyline and scenario families describe a convergent world with the same trend in global population and economic and cultural globalization as is described in A1.

The B1 storyline differs from A1 in that it involves economic structures rapidly changing toward a more global service and information economy, with reductions in throughput (material intensity) and increased reliance on clean and resource-efficient technologies. The emphasis is on global solutions to sustainability (economic, social, and environmental) issues, including equity, but with no new climate initiatives. Finally, the B2 storyline describes a world in which the emphasis is on local solutions to sustainability (economic, social and environmental) issues. Population continuously rises from current levels to 10.2 billion in 2100. There is an intermediate level of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. All the scenarios envision a more materially affluent future, with gross world product rising by between a factor of 10 (lowest-growth scenario) and 26 (highest-growth scenario) in the 100-year period.

In accordance with a decision by the IPCC Bureau in 1998 to release draft scenarios to climate modelers for their input in the Third Assessment Report, a "marker scenario" was selected from each of the scenario families, including the subdivisions within the A1 storyline. Thus, there is one marker scenario each for A1FI, A1T, A1B, A2, B1, and B2. While marker scenarios are also considered to be no more or less likely than the other scenarios, they are considered to be the most representative of the essential storyline from which they are derived. The A1FI marker scenario forecasts global annual carbon dioxide emissions rising relatively steeply and then eventually stabilizing at approximately 29 billion tons. The A1T marker scenario forecasts global annual carbon dioxide emissions to peak at approximately 13 billion tons in 2040, with annual emissions declining thereafter to an eventual rate of 5 billion tons in 2100. The A1B marker scenario forecasts global annual carbon dioxide emissions to peak at approximately 17 billion tons in 2050, with annual emissions declining thereafter to an eventual rate of 14 billion tons in 2100.

Additionally, the A2 marker scenario forecasts global annual carbon dioxide emissions to rise steadily throughout the twenty-first century, ultimately reaching 29 billion tons in 2100. The B1 marker scenario forecasts global annual carbon dioxide emissions to follow a pattern very similar to that of A1T, peaking at approximately 12 billion tons in 2040, with annual emissions declining thereafter to an eventual rate of 4 billion tons in 2100. Finally, the B2 marker scenario forecasts global annual carbon dioxide emissions to rise relatively slowly throughout the twenty-first century to an eventual rate of approximately 13 billion tons in 2100.

Therefore, in terms of annual carbon dioxide emissions in 2100, we can group together the marker scenarios for A1FI and A2 (29 billion tons), A1B and B2 (13–14 billion tons), and A1T and B1 (4–5 billion tons). The A1T and B1 storylines whose marker scenarios provide the most favorable view of future carbon dioxide emissions have much in common. They share a view of a future world in which the forces of globalization have led to extensive cultural interaction, increased material affluence, convergence of material standards of living, and declines in population. Importantly, they both envision an economic transition that either involves the reliance on nonfossil fuels (A1T) or substantial increases in energy efficiency and reductions in throughput.

The intermediate marker scenarios A1B and B2 arrive at a similar annual rate of carbon dioxide emissions in 2100, but for different reasons. A1B forecasts an eventual decline in population, rapid economic growth and technological innovation, and a balance of fossil and nonfossil fuels, while B2 features higher population and slower economic growth and technological innovation, and a variety of different local responses to the imperatives of sustainability. Finally, the high marker scenarios A1FI and A2 suggest that very high rates of annual carbon dioxide emissions can come about either from rapid economic growth, globalization, and extensive reliance on fossil fuels by a declining population, or slower economic growth and regionalism by a continually rising population. It is important to note that even in the most favorable scenarios describe above, cumulative carbon dioxide (and other greenhouse gas) emissions will increase over the next 100 years.

According to the U.S. Energy Information Administration (1999), U.S. carbon emissions from energy use are projected to increase by an average of 1.3 percent a year through 2020, from 1,495 million metric tons (measured in carbon content) in 1998 to 1,787 million metric tons in 2010 and 1,979 million in 2020. As a point of reference, energy-related carbon emissions for the United States in 1990 were 1,345 million metric tons. Although energy demand is forecasted to be higher in 2020 because of higher projected economic growth, travel, and fuel consumption for electricity generation, higher nuclear generation and more rapid efficiency improvements moderate the growth in emissions. In their reference case scenario for world carbon dioxide emissions, the U.S. Energy Information Administration (1998a) forecasts that annual world emissions of carbon dioxide will rise from 7.2 billion tons in 2000 to 9.8 billion tons in 2020.

Predictions Regarding Global Climate Change

It is more difficult and controversial to predict global climate change than it is to predict future greenhouse gas emissions. Climate models are extremely complex, and as our understanding of the world's climate improves, so too will our ability to model and predict climate change caused by anthropogenic greenhouse gas emissions. To see this, consider the evolution of IPCC predictions during the 1990s. In 1990, the IPCC had estimated average increases in temperatures at Earth's surface ranging from 3° to 10°F by 2050, with the most likely increase being nearly 5°. The IPCC also issued a midrange estimate for global warming in the longer term (several hundred years into the future) of 18°F. In January 1996, the IPCC lowered the projected rate of warming over the next century by about 30 percent compared to its 1990 assessment. This downward adjustment occurred as a consequence of including more variables and interactive effects into the climate change model. For example, the new model included emissions of traditional pollutants such as sulfates and carbonaceous aerosols, which cool the atmosphere by reflecting incoming solar radiation and altering the reflective properties of clouds. These sulfates and aerosols may have masked one-half of the heat-trapping effects of increased concentrations of greenhouse gases. The new model also included increased carbon dioxide sequestration by forests whose growth will be stimulated by a more carbon-rich atmosphere.

Another reason for the downward revision in the climate change forecast is the decline in projected chlorofluorocarbon emissions due to international control actions taken within the structure of the Montreal Protocol since 1990. The 1996 estimates for global warming, based on moderate population growth and economic expansion, and a lack of international greenhouse gas–control efforts, call for a mean surface temperature rise of between 1° and 3.5°C by 2100.

One direct implication of global warming and temperature increases in polar areas is the potential for large-scale melting of ice caps, resulting in a rise in sea levels (estimated in 1996 by the IPCC to be around 0.5 meter by 2100) and widespread flooding in low-lying coastal areas. If the predictions regarding global warming prove to be true, then the damage from rising sea levels will disproportionately harm poorer countries without the income to build dikes and other engineering works to counteract rising seas, and may result in large-scale refugee displacements (hundreds of millions or more people leaving Bangladesh, the Nile Delta, and coastal China, among other areas). While current models predict a global average increase in precipitation, this increase is not expected to be uniformly distributed. In particular, higher latitudes are expected to experience an increase in precipitation because of poleward transport of atmospheric moisture generated from increased evaporation in lower latitudes. This increased spring evaporation will tend to dry out many soils in lower latitudes, leading to less moisture being available for evaporation and rainfall during the summer, resulting in sharper summer droughts (Karl et al. 1997). More generally, the pace of the greenhouse effect is predicted to proceed more rapidly than the natural ability of many plant and animal species to adjust, hastening the rate of extinctions.

Karl et al. (1997) observed that small increases in average daily temperatures cause a disproportionate percentage increase in the frequency of extremely hot days and heat waves. Cold spells will still occur, but will be less likely. Using the Chicago area as an example, Karl et al. point out that with "just a three degree C increase in the average July temperature, the probability that the heat index (a measure that includes humidity and measures overall discomfort) will exceed 49 degrees C (120 degrees F) sometime during the month increases from one in 20 to one in four" (p. 80). An interesting effect of global warming appears to be that warming affects daily minimum temperatures far more than daily maximums, thus lengthening the growing season in many temperate areas around the world. Dai et al. (1997) point out that this increase in daily minimum temperatures coincides with (and thus might be explained by) a global increase in thick, precipitating clouds, as might be expected from the greenhouse effect, and these clouds tend to reduce nighttime cooling. Moreover, while earlier analysis of global warming suggested an increase in the frequency and intensity of tropical cyclones and hurricanes, more recent work suggests that there will not necessarily be a significant global increase in tropical storm activity.

The Hadley Center for Climate Prediction and Research in the United Kingdom produced a number of predictions regarding global climate change and its impacts in 1999. A summary of their predictions based on unmitigated anthropogenic greenhouse gas emissions is provided below. The Hadley Center predicts that with unmitigated emissions, global average temperature will increase by 3°C and mean sea level will rise by 40 centimeters by the 2080s compared to the present (Hadley Center 1999). Land areas will warm twice as fast as oceans; winter high latitudes are also expected to warm more quickly than the global average, as are areas of northern South America, India, and southern Africa. The 40-centimeter rise in mean sea level forecasted by the 2080s is estimated to increase the annual number of people flooded from 13 million to 94 million. Sixty percent of this increase will occur in southern Asia (along coasts from Pakistan, through India, Sri Lanka and Bangladesh to Burma), and 20 percent will occur in Southeast Asia (from Thailand to Vietnam including Indonesia and the Philippines). Large changes in precipitation, both positive and negative, are seen, largely in the Tropics.

With unmitigated emissions, the Hadley Center predicts a substantial dieback of tropical forests and tropical grasslands by the 2080s, especially in northern South America and central southern Africa. Considerable growth of forests is predicted to occur in North America, northern Asia, and China. The center predicts that the absorption of carbon dioxide by vegetation will increase during the twenty-first century, but this sink is lost in the 2070s with unmitigated emissions due to a dieback in tropical vegetation. With unmitigated emissions, the Hadley Center model predicts that by the 2080s there will be large changes in the availability of water from rivers. Substantial decreases are predicted for Australia, India, southern Africa, most of South America and Europe, and the Middle East. Increases are seen across North America, Asia (particularly Central Asia) and central eastern Africa. Climate change and carbon dioxide increases due to unmitigated emissions are forecasted by the Hadley Center to increase grain harvests at high and mid-latitudes, such as North America, China, Argentina, and much of Europe, by the 2080s. At the same time, grain harvests in Africa, the Middle East and, particularly, India are expected to decrease.

In terms of human health impacts, the Hadley Center forecasts that an estimated 290 million additional people worldwide will be at risk of falciparum malaria (clinically more dangerous than the more widespread vivax malaria) due to climate change from unmitigated emissions by the 2080s. The greatest increases in risk are projected for China and Central Asia. Epstein (2000) reports that predicted increases in temperature will broaden the range of mosquitoes carrying not only malaria, but also dengue fever, yellow fever, and several kinds of encephalitis. Predicted increases in flooding events will not only create ideal mosquito habitat, but will also expand the spread of cholera and other water-borne diseases. The Hadley Center predicts that human-induced warming will reduce the risk of mortality in many large temperate-zone cities, as the estimated reduction in winter-related mortality exceeds the increase in heat-related summer mortality.

In 2000, the U.S. Global Change Research Program (USGCRP; National Assessment Synthesis Team 2000) issued a national assessment of predicted climate change impacts on the United States, key elements of which are summarized below. The national assessment predicts that the warming in the twenty-first century will be significantly larger than in the twentieth century. Scenarios examined in the assessment, which assume no major interventions to reduce continued growth of world greenhouse gas emissions, indicate that temperatures in the United States will rise by about 5–9°F (3–5°C) on average during the twenty-first century, which is more than the projected global increase. This rise is very likely to be associated with more extreme precipitation and faster evaporation of water, leading to greater frequency of both very wet and very dry conditions. The assessment reports that natural ecosystems (as opposed to agricultural lands or timber plantations) are especially vulnerable to the harmful effects of climate change as there is often little that can be done to help them adapt to the projected speed and amount of change. Some ecosystems that are already constrained by climate, such as alpine meadows in the Rocky Mountains, are likely to face extreme stress, and may disappear entirely. It is likely that other more widespread ecosystems will also be vulnerable to climate change. One of the climate scenarios used in the assessment suggests the potential for the forests of the American Southeast to break up into a mosaic of forests, savannas, and grasslands. Several of the climate scenarios suggest possible changes in the species composition of the northeastern forests, including the loss of sugar maples. Major alterations to natural ecosystems due to climate change could possibly have negative consequences for our economy, which depends in part on the sustained bounty of our nation's lands, waters, and native plant and animal communities.

The USGCRP assessment also includes an examination of the potential impacts of climate change on different regions of the United States. For example, rising sea levels will very likely cause further loss of coastal wetlands (ecosystems that provide vital nurseries and habitats for many fish species) and put coastal communities at greater risk of storm surges, especially in the Southeast. Reduction in snowpack will very likely alter the timing and amount of water supplies, potentially exacerbating water shortages and conflicts, particularly throughout the western United States. The two models used in the assessment forecast annual average temperature increases ranging from 3° to over 4°F (2°C) by the 2030s and 8–11°F (4.5–6°C) by the 2090s. The two models project increased rainfall during winter, especially over California, where runoff is projected to double by the 2090s. In these climate scenarios, some areas of the Rocky Mountains are projected to get drier. Both models project more extreme wet and dry years. The melting of glaciers in the high-elevation West and in Alaska represents the loss or diminishment of unique national treasures of the American landscape. Large increases in the heat index (which combines temperature and humidity) and increases in the frequency of heat waves are very likely. The assessment argues that these changes will, at minimum, increase discomfort, particularly in cities. It is very probable that continued thawing of permafrost and melting of sea ice in Alaska will further damage forests, buildings, roads, and coastlines, and harm subsistence livelihoods. In various parts of the nation, cold-weather recreation such as skiing will very likely be reduced, and air conditioning usage will very likely increase.

The USGCRP assessment also predicts some positive effects from global climate change in the twenty-first century. For example, crop and forest productivity is likely to increase in some areas for the next few decades due to increased carbon dioxide in the atmosphere and an extended growing season. The assessment states that some U.S. food exports could increase, depending on impacts in other food-growing regions around the world, and that a rise in crop production in fertile areas could cause prices to fall, benefiting consumers. Other benefits that are possible include extended seasons for construction and warm-weather recreation, reduced heating requirements, and reduced cold-weather mortality.

Finally, the USGCRP assessment points out that there are also very likely to be unanticipated impacts of climate change during the next century. Such surprises may stem from unforeseen changes in the physical climate system, such as major alterations in ocean circulation, cloud formation, or storms, and unpredicted biological consequences of these physical climate changes, such as massive dislocations of species or pest outbreaks. In addition, unexpected social or economic change, including major shifts in wealth, technology, or political priorities, could affect our ability to respond to climate change. Policy makers are confronted with the challenge of devising greenhouse gas policy in the context of uncertainty. Thus, we are conducting a *natural experiment* on the planet, the outcome of which may range from moderate to catastrophic, and which will last well beyond the human time scale of lifetimes and generations.

The Evidence Regarding Global Climate Change

Scientists have found evidence from a variety of sources that is consistent with climate change models linking greenhouse gases to global warming. The IPCC reported in January 1996 that over the last 100 years, global mean surface temperatures have increased by between 0.3° and 0.6°C, and mean sea level has risen by between 1 and 2.5 millimeters per year. The IPCC concluded rather cautiously that it is unlikely that this rise in global temperatures is entirely due to natural causes, stating that "the balance of evidence suggests a discernible human influence on global climate." In April 2000, the IPCC issued a stronger draft message in which the organization stated "that there has been a discernible human influence on global climate." The National Research Council (2000) reports that accelerated warming in the late 1990s has raised the IPCC (1996) warming estimate during the twentieth century to between 0.4° and 0.8°C. The World Bank (1999) reports that the twentieth century was the warmest in 600 years, and 14 of the warmest years since 1860 have occurred in the 1980s and 1990s. The World Bank also reports that winter seawater temperature in latitudes above 45 degrees north have risen by 0.5°C since the 1980s, and that in 1999, the International Ice Patrol did not report a single iceberg south of 48 degrees north latitude.

In its assessment of climate change effects on the United States, the USGCRP (2000) reports that the average annual U.S. temperature has risen by almost 1°F (0.6°C) during the twentieth century, and precipitation has increased nationally by 5 to 10 percent (mostly due to increases in heavy downpours). The assessment reports that these trends have been most apparent over the past few decades. The Hadley Center (1999) reports that the free atmosphere (at a height of 3–5 km) has clearly warmed over the last 35 years, although not always in concert with the surface, and that the extent of Arctic sea ice has decreased over the last three decades. As pointed out earlier, analysis of the observed rise in global temperatures indicates that the increase is due in large part to increases in daily minimum temperatures. For example, Easterling et al. (1997) found that, while global daily maximum temperatures have been rising at a rate of 0.88°C each century, daily minimum temperatures have been rising at the rate of 1.86°C each century. Increases in cloudiness are believed to have caused much of this effect.

Improved methods of reconstructing and then explaining Earth's climatic history is essential to understanding the extent to which the current warming trend is anthropogenic. Methods of reconstructing Earth's climatic history include tree-ring analysis, ice cores, corals and sediments, and bore-hole temperatures. As Overpeck (2000) describes in his review of the recent scientific literature on the world's climatic history, natural factors such as variation in solar output or volcanic eruptions that episodically reduce solar heating at the surface account for many features of the pre-industrial portion of the temperature record. Such natural mechanisms can explain only a fraction of the total warming that took place in the twentieth century, leaving us with the likelihood that human-induced warming is under way.

One source of controversy over the observed record of global climate change has been the disparity between rising surface temperature readings and steady satellite temperature readings for the lower and mid-troposphere (that portion of the atmosphere that extends from the surface to about 8 kilometers above the surface). Climate change models predict that the lower and mid-troposphere should warm at least as much as the surface, and therefore the satellite data appear to invalidate the models. The satellite data have only been available since 1979, which makes it difficult to infer any meaningful trend in the data.

Nevertheless, some have used this disparity to cast doubt on the reliability of the surface temperature record and the claims made by the IPCC that there is a discernible human influence on global climate. A special panel was assembled by the National Research Council to assess this disparity. The National Research Council (2000) reports that the warming trend in global mean surface temperatures is "undoubtedly real" and is "substantially greater" than the average rate of warming during the twentieth century. The council states that the disparity (which was reduced somewhat by improved corrections in the microwave sounding units used to gauge tropospheric temperature) in no way invalidates the conclusion that Earth's surface temperatures are rising. The panel stated that the lack of warming in the troposphere in the 20-year period may have been due to natural causes such as volcanic eruptions and to human causes such as ozone depletion in the stratosphere.

Skeptics of global climate change have also pointed to the fact that observed surface temperature warming has so far been very modest, less than some have predicted, thus arguing that dire forecasts of future warming are overstated. Climate modelers have responded that a good deal of the warming should be occurring in the world's oceans, though the historical temperature record was thought to be too spotty to get a definitive answer. Thus, the United Nations sponsored the Global Oceanographic Data Archaeology and Rescue Project, which over the last seven years has resulted in an additional 2 million ocean temperature profiles being added to the historical record. Levitus et al. (2000) report that these data show a marked warming in the world's oceans over the last half of the twentieth century. Kerr (2000) reports that the increased heat content found by Levitus and colleagues is roughly what climate models have predicted.

There are a variety of other more regional sources of evidence for global climate change. Myneni et al. (1997) report that since the early 1980s the active growing season has increased by approximately 12 days in the Northern Hemisphere between 45 and 70 degrees north latitude. Much of the increase is concentrated in the spring and appears to be associated with an earlier disappearance of snow cover. The USGCRP (2000) reports that during the twentieth century, temperatures in the western United States have risen by 2–5°F (1–3°C). The region has generally had increases in precipitation, with increases in some areas greater than 50 percent. However, a few areas, such as Arizona, have become drier and experienced more droughts. The length of the snow season decreased by 16 days from 1951 to 1996 in California and Nevada, and extreme precipitation events have increased. Epstein (2000) reports that the elevation at which temperatures are always below freezing has ascended almost 500 feet in the Tropics, and mosquitoes carrying malaria and dengue fever now occur at higher elevations than before. For example, nineteenth-century European colonists in Africa avoided malaria by settling in cooler mountain areas, but many of these havens are now compromised. Epstein observes that insects and the diseases they carry have been found at higher elevations in Central and South America, east and central Africa, and Asia.

The Global Climate Coalition has been a major dissenting voice on the science of global climate change. While there are scientists on both sides of the global-warming issue whose past work has earned them substantial respect, concern has been voiced about the objectivity of the science supported by coal and oil companies. In particular, Gelbspan (1995) has reported that many of the most prominent scientists arguing against the global-warming model have received consulting incomes from coal, oil, and other interests aligned with the Global Climate Coalition. Although Gelbspan's statements have been interpreted by some to have defamed the character of these scientists by suggesting research bias, nevertheless, the naysayers have failed to impact the dominant view of climate change held by the scientific community. Some argue that scientific uncertainty regarding the extent and impacts of future global climate change must be resolved before costly preventative measures are taken. The problem with this argument is that by the time we know with certainty that global climate change is upon us and that it is due to human activity, it will be too late. The time scale required to reverse greenhouse gas concentrations in the atmosphere makes the problem irreversible from the standpoint of the next few human generations at risk. Therefore, the policy decision must be made in the context of uncertain future impacts.

Faucheaux and Froger (1995) argue that, in fact, most environmental problems occur in a context of uncertainty, irreversibility, and complexity, and so the policy challenges that have been exemplified by global warming generalize to other environmental dilemma settings. This argument leads to the *precautionary principle*, which suggests that precautionary measures should be taken when evidence suggests that an activity is generating costly or irreversible harms, even if there is still some uncertainty over the extent or the mechanics of the harms. It is less clear what those measures should be.

International Action on Global Climate Change

The IPCC, which was formed in 1988, issued its First Assessment Report in 1990 in which the organization highlighted the importance of forming an international agreement on climate change. International negotiations were also advocated by the Second World Climate Conference, also held in 1990. As a result, the United Nations General Assembly opened negotiations on a framework convention on climate change in 1990, and created the Intergovernmental Negotiating Committee to conduct these negotiations. Thus, as early as 1990 it was recognized that the global climate is a global common-pool resource (CPR), and that international action is necessary to avoid a potentially catastrophic “tragedy of the commons.” As with managing the world’s marine fishery CPRs, lack of international coordination and cooperation will likely result in many countries failing to take adequate measures, thus free riding on the control efforts undertaken by other countries.

The question of what level of greenhouse gas control is in the best interests of a particular country is very difficult to answer for a variety of reasons. Regional effects are known with much less certainty than are global effects, yet in all likelihood, some regions and countries will be much more impacted than others. Moreover, northerly countries such as Canada, Norway, Sweden, Finland, and Russia may actually benefit from global warming.

How can sovereign nations structure global-warming policy when the regional effects are largely unknown? Additonally, given the high degree of asymmetry between high- and low-income countries, diversity also exists in the extent to which nations can engineer around negative impacts of global warming. Countries also differ in terms of the educational attainment and political empowerment of their citizens. Thus, from an international relations perspective, countries are diverse and are unlikely to have national interests that are mutually consistent. Nevertheless, most all governments see a benefit in at least some control of greenhouse gas emissions as a type of insurance against the risk of negative future impacts.

The Earth Summit

The idea of sustainable economic development was made prominent following the publication in 1987 of the World Commission on Economic Development (Brundtland Commission) report *Our Common Future.* Concerns for integrating biodiversity and climate change with sustainable development strategies led to representatives of national governments meeting in May and June of 1992 at the United Nations Conference on Environment and Development (UNCED), frequently referred to as the “Earth Summit.” The United Nations Framework Convention on Climate Change (UNFCCC), which the Intergovernmental Negotiating Committee had adopted by consensus in May 1992 in New York, was opened for signature during the Rio de Janeiro meetings of the Earth Summit. A total of 181 governments and the European Community are Parties to the Convention. To become a Party, a country must ratify, accept, approve, or accede to, the Convention. Parties meet regularly at the annual Conference of the Parties to review the implementation of the Convention and continue talks on how best to tackle climate change. The Convention set an “ultimate objective” of stabilizing atmospheric concentrations of greenhouse gases at safe levels. Such levels, which the Convention does not quantify, are to be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner.

The Convention divides countries into Annex I Parties and unlisted “non-Annex I” countries. Annex I Parties are industrialized nations made up of wealthy Organization for Economic Cooperation and Development (OECD) countries and economies in transition (EITs), such as the Russian Federation and various central and eastern European countries, that have historically contributed the most to climate change. The per capita emissions from these countries are higher than those of most developing countries, and they have greater financial and institutional capacity to address the problem. The principles of equity and "common but differentiated responsibilities" enshrined in the Convention therefore require these Parties to take the lead in modifying longer-term trends in emissions. To this end, Annex I Parties committed themselves to adopting national policies and measures with the non-legally binding aim of returning their greenhouse gas emissions to 1990 levels by the year 2000. The OECD members of Annex I are also listed in Annex II of the UNFCCC. Annex II countries have a special obligation to provide "new and additional financial resources" to developing countries to help them tackle climate change, as well as to facilitate the transfer of climate-friendly technologies to both developing countries and EITs. A Global Environment Facility (GEF) was set up to coordinate the transfer of support from Annex II Parties to the non-Annex I developing countries and EITs in Annex I. The UNFCCC entered into force in 1994 after having been ratified by 50 nations.

The record is mixed in terms of the success of Annex I countries in meeting their UNFCCC goal. The European Environment Agency reported in June 2000 that a drop in greenhouse gas emissions in Germany and the United Kingdom helped drive total European Union emissions down 2 percent from 1990 to 1998. A survey by the World Energy Council, however, indicates that between 1990 and 1996 carbon dioxide emissions had increased worldwide by 4 percent. The United States is prominent in its failure to meet the Earth Summit target. In 1990, the United States produced 1.346 billion metric tons of carbon-equivalent emissions due to the combustion of fossil fuel, and by 1999 this figure had increased by approximately 12 percent to 1.51 billion metric tons. Some of this rise in carbon dioxide can be attributed to low inflation-adjusted fossil-fuel energy prices, which price-out alternative energy technologies and reduce the incentive to conserve. For example, the average fuel efficiency of U.S. automobiles has declined over the last few years, reflecting increased sales share for more gas-guzzling minivans and sport utility vehicles. Another part of this rise can be attributed to an increased pace of economic growth ever since the recession in 1990–91. The U.S. economy grew 33 percent during the 1990s.

The UNFCCC also established a Conference of Parties, to which signatory countries agreed to report their current emissions levels and provide plans for reducing them. The Conference of Parties holds annual meetings. In the First Conference of Parties, held in April 1995, 120 countries agreed to begin talks in Berlin on achieving further reductions after 2000. The Berlin talks were intended to find ways to extend commitments made at the Earth Summit. This was a rancorous meeting, as lobbyists argued their different interpretations of climate data, and little in the way of new policy was accomplished, though later in 1995, the IPCC issued its Second Assessment

Report in which it announced evidence of an anthropogenic source of recent global warming. A new round of meetings was held in July 1996 in Geneva. At these meetings, the United States officially changed its position from one supporting voluntary targets (Earth Summit) to one supporting industrialized nations' entering into a binding pact to reduce greenhouse gas emission levels. As Undersecretary of State Tim Wirth stated, "We're going to miss the target and so is [virtually] everyone else. A voluntary approach doesn't do it. Talk is cheap. . . . We believe binding international commitments are going to be necessary. . . . Continuing use of nonbinding targets that are not met makes a mockery of the treaty process" (*San Francisco Chronicle,* 18 July 1996). A split in industry positions was also exposed at the Geneva meetings. The Global Climate Coalition, representing coal and oil industry interests, continued to argue against stringent targets and binding controls, while the International Climate Change Partnership—representing Dow, Du Pont, and General Electric—offered qualified support for binding controls.

The Kyoto Protocol

In December 1997, the Third Conference of Parties adopted the Kyoto Protocol to the United Nations Framework Convention on Climate Change in Kyoto, Japan. The Kyoto Protocol commits Annex I Parties to individual, legally binding targets to limit or reduce their greenhouse gas emissions, adding up to a total cut of at least 5 percent from 1990 levels in the period 2008 to 2012. The individual targets for Annex I Parties are listed in the Kyoto Protocol's Annex B, and range from an 8 percent cut for the European Union (EU) and several other countries, to a 10 percent increase for Iceland. Under the terms of the Kyoto Protocol, the EU may redistribute its target among its 15 member states. It has already reached agreement on such a scheme, known as a "bubble." By March 1998, the Kyoto Protocol was opened for signature at the United Nations headquarters in New York, and 84 countries became signatories to the Kyoto Protocol by early 1999.

The Kyoto Protocol also establishes three incentive-based economic instruments that are designed to help Annex B countries reduce the cost of meeting their emissions targets. These instruments are *joint implementation* (described in chapter 9), *emissions trading,* and the *clean development mechanism.* These instruments allow Annex I nations to meet their emissions target by either producing or acquiring emissions reductions in other countries, most commonly lower-income developing countries. *Joint implementation* projects allow an Annex I Party to receive emission credits for projects that reduce emissions or enhance emissions-absorbing sinks in other Annex I countries. It is specifically indicated in the Protocol that *trading* and joint implementation are supplemental to, rather than a substitute for, domestic actions. The *clean development mechanism* assists developing nations in achieving sustainable development by directing environmentally friendly investment into their economies from Annex I Parties and corporations. As of July 2000, the operational details of these incentive-based instruments had not yet been fully established.

In order to enter into force, the Protocol must be ratified by 55 Parties to the Convention, including Annex I Parties accounting for 55 percent of carbon dioxide emissions from this group in 1990. By March 15, 1999, a total of 84 countries had signed the Kyoto Protocol, including all but two of the Annex I countries, Hungary and Iceland. Only 10 nations had actually ratified or acceded to the Kyoto Protocol, none being an Annex I country.

Policy Studies: The Economics of Controlling Greenhouse Gas Emissions

Arguably, the easiest place to start implementing policy to control greenhouse gas emmissions is to eliminate subsidized fossil-fuel consumption around the world. *The Economist* (20 July 1996) points out that countries such as Germany and Russia subsidize coal mining. In particular, Roodman (1996) reports that in 1995 Germany provided its domestic coal producers with a subsidy of $119 per ton, while Russia paid $3.7 billion in coal production subsidies in 1994. Roodman goes on to report that, in 1996, developing countries paid $101 billion in fossil-fuel and power subsidies. *The Economist* argues that removing all subsidies for the burning of fossil fuel would provide consumers with an incentive to conserve and promote the market for fossil-fuel alternatives, which together could cause greenhouse gas emissions to decline by 4 to 18 percent. Interestingly, many in the fossil-fuel industry as well as environmentalists support removal of these subsidies. However, removal of the subsidies would disproportionately hurt low-income people, and so it would need to be accompanied by a compensatory income-transfer scheme.

The U.S. Energy Information Administration (EIA) undertook an analysis of the cost to the United States of meeting its obligations under the Kyoto Protocol (USEIA 1998b). The EIA considered a number of different scenarios based on the extent to which the reductions are achieved domestically rather than through the acquisition of emission credits through trading, joint implementation, or clean development. These ranged from the 1990 + 24 case, in which U.S. carbon emissions are 24 percent above 1990 levels and approximately 80 percent of the Kyoto reduction is accomplished from the acquisition of emission credits, to the 1990–7 case, in which the Kyoto reduction is entirely accomplished through domestic emission reductions. In its 1998 analysis of the Kyoto Protocol, the EIA assumed that a carbon price would be applied to each of the energy fuels at its point of consumption, relative to its carbon content. The carbon price would not be applied directly to electricity, but would be applied to the fossil fuels used for electricity generation and reflected in the delivered price of electricity. The EIA estimated that by 2010, the carbon price necessary to achieve the targets ranges from $67 per metric ton (1996 dollars) in the 1990 + 24 case to $348 per metric ton in the 1990–7 case. In the more restrictive cases such as 1990–7, the carbon price escalates rapidly to achieve the more stringent reductions but then declines over the next 10 years of the forecast horizon. Cumulative investments in more energy-efficient and lower-carbon equipment, particularly for electricity generation, reduce the cost of compliance in the later years. These carbon prices would in turn raise the price of energy based on relative carbon content. For example, delivered coal prices would rise by between 152 and nearly 800 percent, average electricity prices would rise by between 20 and 86 percent, average delivered natural gas prices would rise by between 25 and 148 percent, and average petroleum prices would rise by between 12 and 62 percent. Clearly, we can see that the trading of credits, joint implementation, and clean technology options substantially reduce the economic impacts of compliance with the Kyoto Protocol.

Over the long run these higher energy prices would in turn lead to increased energy efficiency (as measured by reduced energy intensity, calculated as energy per dollar of real gross domestic product [GDP]) and reduced reliance on carbon-intensive energy sources such as coal. Higher fossil-fuel energy prices also have implications for the macroeconomy. The EIA estimated the macroeconomic impacts of the Kyoto Protocol using the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy. Using this model, the EIA estimated that the average annual cost to the U.S. economy (in constant 1992 dollars) from compliance with the Kyoto Protocol ranges from $128–283 billion for the 1990–7 case to $77–109 billion for the 1990 + 24 case. Based on a projected real GDP of $9,425 billion for the 2008–2012 time period in which the reductions are to occur, these annual costs to the economy are estimated to range from a high of 3 percent to a low of 0.8 percent of GDP. The more restrictive cases led to a larger reduction in projected economic growth in the period between 2005 and 2010, though the economy was projected to quickly rebound so that impacts on economic growth during the longer 2005–2020 time period are estimated to be minimal.

Boyd, Krutilla, and Viscusi (1995) sought to determine the level of energy taxation, conservation, and carbon dioxide emissions control that can be economically justified based on a net benefit criterion. The analysis by Boyd and colleagues offers a range of different scenarios, including low, medium, and high environmental benefits, and different assumptions regarding the extent to which firms can respond to higher energy prices by conserving on the use of energy in production. It is also important to point out that the Boyd et al. study utilizes a "no-regret" perspective in which the computed benefits of reducing carbon dioxide emissions are based on the *current* or *secondary* harms of fossil-fuel burning—particulates, sulfur dioxide, ozone, nitrogen oxides, and carbon monoxide—and not on the possible future primary harms from carbon dioxide emissions. This method of computing the benefits of carbon taxation is referred to as a "no-regret" measure because it is based on known current impacts of fossil-fuel burning rather than more conjectural future global-warming impacts. Thus, their study uses *current benefits* and costs associated with reduced use of fossil fuels to justify reductions in carbon dioxide emissions, which generate uncertain long-term benefits that are secondary to the analysis.

One of the interesting findings from this study is that under the assumption that very little energy conservation is possible in production, reducing carbon dioxide emissions by up to around 7 percent imposes insignificant economic costs. Each additional 7 percent increase in carbon dioxide emissions causes progressively higher economic costs. These costs "increase strikingly" for reductions beyond 35 percent. When substantial energy conservation is assumed to be possible, the economic costs of reducing carbon dioxide are much lower, and the cost of a 50 percent reduction is only about 1.4 percent of real gross national product (GNP).

The principal findings of Boyd, Krutilla, and Viscusi are:

- Current energy prices are lower than socially optimal. Depending on the scenario used, fossil-fuel energy tax rates of between 20 and 70 percent are socially optimal. Even in the most conservative scenario, tax rates of 20 percent on coal, 10 percent on oil, and 5 percent on natural gas are socially optimal.
- Under the assumption that firms cannot easily reduce their use of energy in response to higher prices, the analysis finds that a 12 percent reduction in carbon dioxide is socially optimal, and a reduction of up to 20 percent can be accomplished before social welfare is reduced relative to the no-control (base) case.
- Under the assumption that firms can more easily reduce their use of energy in response to higher energy prices, a 29 percent reduction in carbon dioxide emissions is found to be socially optimal, and close to a 50 percent reduction could occur before social welfare is reduced below the no-control case.

- Carbon taxation is mildly regressive, taxing a larger proportion of the incomes of the poor relative to the rich, as is the case with most sales taxes, for example.

Thus, the Boyd et al. (1995) study indicates that relatively substantial reductions in carbon dioxide emissions are consistent with a net monetary benefit-based policy standard.

As is made clear by the Boyd et al. study, burning fossil fuels loads the atmosphere not only with carbon dioxide but also with a host of other damaging pollutants. Therefore, reductions in the use of coal and other carbon-intensive fossil fuels produce ancillary benefits in the form of current improvements in air quality. Burtraw and Toman (1997) estimated that these ancillary benefits could be on the order of 30 percent of the incremental cost of greenhouse gas reduction, although they report that the size depends on the location and scale of greenhouse gas reductions among other factors. Boyd et al. (1995) estimated that the total (excluding global warming) environmental harms caused by fossil-fuel burning in the United States range from 0.2 to 4 percent of real GNP, with a midpoint value of about 2 percent. Nordhaus and Yang (1996) estimate these economic costs to be in the range of 1 to 2 percent.

As mentioned above, the Boyd et al. study computes the benefits of carbon taxation based on the current or secondary effects of fossil-fuel burning, rather than on the possible future or primary effects caused by carbon dioxide emissions. In a survey of this literature, Ekins (1996) found that these secondary benefits of reducing carbon dioxide are of the same order of magnitude as the costs of medium to high levels of carbon dioxide abatement. Moreover, these secondary benefits are generally estimated to be higher than the primary benefit associated with less global warming. Clearly, the existence of these secondary benefits greatly reinforces the case made by environmental economists for current action on carbon dioxide emissions.

Nordhaus and Yang (1996) assumed a general equilibrium approach to analyze the economics of climate change policy, but their economic model distinguishes costs, impacts, and policies for different regions of the world. They found the efficient global carbon tax to be about $6 per ton by 2000, rising to $27 per ton by 2100. Under this scenario, China and Russia will be confronted with much higher emissions controls than Japan and Europe, and Nordhaus and Yang acknowledge that in the current policy environment, the efficient level of control is unlikely to be obtained. Nordhaus and Yang also found the discounted net economic gain from an international cooperative effort in climate change policy to be about $300 billion relative to noncooperative efforts by various governments, and $344 billion relative to a “no-abatement” benchmark.

Azar and Sterner (1996) criticized the Nordhaus and Yang study and similar studies on several counts, including the use of what they consider to be an excessively high discount rate, excessive pessimism regarding the rate of technical change in energy efficiency and alternative energy technologies, the ignoring of unequal distributions of income and the marginal utility of money around the globe (implying unequal values attributed to statistical lives lost due to global warming), and the assumption that climate change will proceed “as a smooth and predictable process without risk for sudden catastrophic events” (p. 170). Azar and Sterner recomputed the Nordhaus Dynamic Integrated Climate Economic (DICE) model with adjustments for these various shortcomings, with the exception that they could not model the possibility of catastrophic scenarios. They also used a 300- to 1,000-year time horizon. While Nordhaus (1993b) estimated the marginal cost of carbon dioxide emissions to be $5 per ton, Azar and Sterner estimated the marginal cost of carbon dioxide emissions to range from $260 to $590 per ton. The difference is almost entirely due to a weighting of costs in poorer regions of the world and a 3-percentage point lower discount rate.

One lingering question from these studies has to do with the appropriateness of using benefit/cost analytic techniques to guide global-warming policy. Brown (1991) argued that benefit/cost is in fact an inappropriate policy guide. Azar and Sterner identified a number of these controversies and problems. For example, one might ask what the appropriate discount rate should be. Because we cannot determine the extent of future cost-reducing innovation, we also cannot determine with certainty the costs of controlling greenhouse gases. As income is highly unequally distributed, monetization of benefits such as lives saved based on income may lead to unethical conclusions. These problems are worsened by the extremely long time horizon. The Azar and Sterner study provides an indication of how sensitive the optimal greenhouse gas-control policy is to discount rate, rate of technological change, and income distribution. It is not clear how informative these studies are, except that they all point to the need to use pollution taxes or other regulatory instruments to control current and future emissions of carbon dioxide.

The Developing World and Global Climate Change: The Role of Climate-Friendly Technology Transfer and the Clean Development Mechanism

The Annex I Parties to the UNFCCC (Annex B in the Kyoto Protocol) are generally moving toward policy action regarding greenhouse gas emissions and global climate change. Annex I countries are primarily responsible for the buildup of greenhouse gases, and with their disproportionate share of world wealth, they are in the best position to take action. Nevertheless, the problem of anthropogenic global climate change cannot be overcome without the participation of the lower-income countries. For example, while the United States accounts for about 22 percent of annual global carbon dioxide emissions (and a larger share of cumulative emissions), China is now the world's second largest emitter of carbon dioxide, accounting for approximately 12 percent of total annual emissions. Moreover, China's economy grew at a 10 percent average annual rate between 1981 and 1997, and China has relied on its large reserves of coal to fuel this industrialization. According to the World Resources Institute (1998), China is the world's largest consumer of coal, and coal supplies China with 75 percent of its energy. Between 1970 and 1990, energy use in China—largely driven by burning coal—increased by 208 percent. Energy prices have traditionally been heavily subsidized in China, which creates little incentive for energy conservation.

Moreover, much of China's coal consumption occurs in small industrial and municipal boilers, and in millions of cooking stoves and home heaters, for which no alternative fuels are available. Decentralization in China is promoting smaller, less efficient coal-fired electric power plants. Chinese planners take the position that raising per capita incomes and other elements of economic modernization is the highest priority, and that environmental issues cannot be addressed until such development occurs. China's carbon dioxide emissions in 1989 were 18 times as large as in 1952, and its 2010 emissions are predicted to be twice as large as 1996 levels (World Resources Institute 1994 and 1996). It is expected that China will move past the United States as the world's largest single emitter of greenhouse gases some time between 2020 and 2030. While the current Annex I countries were able to utilize coal and other dirtier energy supplies in their industrialization path, the global control of greenhouse gases will be impossible if the current cohort of lower-income countries follows the same path. Therefore, there is a growing recognition of the importance of financial assistance and technology transfer from the Annex I countries to lower-income countries on the path of industrialization.

As mentioned in the previous section of the chapter, the Kyoto Protocol includes an incentive-based program in which Annex B countries can acquire credits toward their emission reduction targets through a program called the Clean Development Mechanism (CDM). The emission reductions created through the CDM must be certified by an independent auditor whose activities are to be funded from a share of the proceeds of CDM projects or transactions. Therefore, before CDM projects are initiated there must be an accreditation procedure for these independent auditors, and an accounting system in place to track the transfer of credits across firms and countries. Before initiation of CDM projects, a prior baseline of carbon (or other greenhouse gas) emissions from the project facility to be upgraded, or the region in question, must be established. The CDM credits are based on the extent to which carbon emissions fall below this prior baseline. Finally, the Kyoto Protocol requires that any CDM project must produce sustainable development benefits for the host country in question, an issue of importance for most lower-income countries. As of July 2000, the CDM was not yet operational.

Blackman (1999) has surveyed the literature on the economics of technology diffusion and has related it to the problem of promoting climate-change policy in developing countries. Blackman states that there are eight types of policy instruments available to speed the diffusion of climate-friendly technology in developing countries: information, factor prices, regulation, credit, human capital, infrastructure, research and development, and intellectual property rights. Blackman argues that the dissemination of *information* is critical in all economic models of technology diffusion. Some examples of policies that may enhance the flow of information about new technologies include demonstration projects, advertising campaigns, the testing and certification of new technologies, and subsidies to technological consulting services. *Factor* (or input) *prices* can also be important in fostering the diffusion of climate-friendly technology in developing countries. In particular, there is considerable evidence that investment in energy-efficient technology is spurred by higher energy prices. Because many developing countries subsidize energy prices, the removal of those subsidies is likely to trigger increased domestic demand for energy-efficient technology. Presumably the regressive nature of removing energy price subsidies would need to be addressed elsewhere in the tax system. *Regulation*, such as energy taxes or pollution taxes, provides the same sort of economic incentives for investment in energy-efficient technology as does the removal of subsidies. Access to *credit* has also been identified as a barrier to the adoption of climate-friendly technology. As will be discussed in much greater detail in chapter 13, large-scale projects funded externally by agencies such as the World Bank have had mixed results at best. Perhaps a more effective approach would be to help develop domestic sources of credit for smaller-scale and better-managed initiatives.

The diffusion of climate-friendly technology also requires investment in *human capital* so that local people understand the new technology and can make it function properly in their specific cultural context, and investment in necessary infrastructure such as energy distribution networks. *Research and development* (R&D) provides a direct impetus to technology diffusion, and therefore the promotion of climate-friendly R&D activities in developing countries will have an obvious beneficial impact. Finally, *intellectual property rights* can be a formidable barrier to technology transfer due to high licensing prices, and therefore subsidized licensing arrangements may be a critical factor in the diffusion of climate-friendly technology in developing countries.

Summary

- There is increasing evidence of a relationship between human emissions of greenhouse gases and Earth's climate. Greenhouse gases include water vapor as well as gases generated directly or indirectly by human activity, including carbon dioxide, chlorofluorocarbons, methane, and nitrous oxide. These gases allow visible light to pass through but trap some heat and prevent it from being radiated into space, and thus operate like a greenhouse. If there were no greenhouse effect on Earth, the surface of the planet would be approximately 33°C colder than it is now, and most ecosystems would collapse.
- Concentrations of carbon dioxide in Earth's atmosphere—the single most important greenhouse gas—have increased from 280 parts per million (ppm) before the advent of industrialization to approximately 360 ppm. Even very conservative estimates predict nearly a doubling of carbon dioxide concentrations by 2100. In 1992, the United States produced 23 percent of all anthropogenic carbon dioxide. The Persian Gulf states of Qatar and the United Arab Emirates (UAE) had the highest per capita annual emissions of carbon dioxide, at 16.9 and 11.5 metric tons, respectively.
- Today's costs of making a substantial reduction in greenhouse gas emissions are relatively large, concentrated, and certain.
- The estimated benefits of substantially reducing greenhouse gas emissions are diffuse across the globe, primarily occur in the future, and are therefore focused on future generations. Thus, from a political economy perspective, greenhouse gas–control policy is expected to be difficult to achieve and relatively unstable to maintain.
- Models of the global climate continue to be refined, and scientists are getting better at predicting global climate, yet the mechanics of global warming, particularly at the regional level, are tremendously complex. As a consequence, the benefits of controlling greenhouse gas emissions are highly uncertain. One important source of uncertainty is the possibility that large amounts of methane now locked in Arctic tundra and permafrost could be rapidly released if some initial degree of atmospheric warming occurs (and polar areas are predicted to experience the largest temperature changes). Another source of uncertainty is the role of cloud cover and rainfall patterns and whether they will reinforce or attenuate warming.

- Global climate change necessitates international coordination and cooperation across countries that are highly diverse in income, religion, culture, population growth rates, and other demographic characteristics, educational attainment, and extent of democratic empowerment.
- In 1992, the United Nations Conference on Environment and Development resulted in 150 countries signing the UN Framework Convention on Climate Change, which pledges Annex I nations (rich industrialized nations and economies in transition) to control emissions of greenhouse gases. Unlike the European Union, the United States is currently behind schedule in reducing greenhouse gases relative to the 1990 benchmark, in part because cheap gasoline has increased the popularity of less fuel-efficient automobiles.
- The Kyoto Protocol commits Annex I Parties to individual, legally binding targets to limit or reduce their greenhouse gas emissions, adding up to a total cut of at least 5 percent from 1990 levels in the period 2008 to 2012.
- The Kyoto Protocol also establishes three incentive-based economic instruments that are designed to help Annex I countries reduce the cost of meeting their emissions targets. These instruments are joint implementation (described in chapter 9), emissions trading, and the clean development mechanism.
- The Energy Information Administration (EIA) estimated the macroeconomic impacts of the Kyoto Protocol using the Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy. Based on a projected real GDP of $9,425 billion for the 2008–2012 time period in which the reductions are to occur, these annual costs to the economy are estimated to range from a high of 3 percent to a low of 0.8 percent of GDP.
- In a number of ambitious studies, environmental economists have found that vigorous control of carbon dioxide emissions can be justified today based solely on the ancillary benefits of reductions in pollutants such as sulfur oxides and dioxides, particulates, and ozone that presently harm people. These studies make a very strong case for action on greenhouse gas emissions based on a “no-regrets” policy.

Review Questions and Problems

1. Write a two-page essay in which you summarize what is known about global climate change. Discuss how the complexity, the long-term nature of the problem, the diffusion of the benefits, the uncertainty regarding global-warming effects, and the international nature of any effective solution make this one of the most important, controversial, and challenging environmental policy problems we face today.

2. Review the concept of the prisoners' dilemma in the appendix to chapter 5. Is it reasonable to model the international coordination problem for control of greenhouse gases as a prisoners' dilemma game? If so, explain the payoff structure in a simple case of a two-country world.

3. What other environmental issues have uncertainty, irreversibility, and potentially large long-term impacts similar to the global-warming issue? Carefully explain your reasoning. How might the policy and political economy implications be similar to those of global warming?

4. Access the report *Climate Change Impacts on the United States* on the Internet (http://www.gcrio.org/NationalAssessment/). Review the forecasted environmental and social impacts of global climate change for a region of the United States.

Internet Links

Carbon Dioxide Information Analysis Center (http://cdiac.esd.ornl.gov/): A key source of climate change data and research at the Oak Ridge National Laboratory.

Clean Development Mechanism and Africa (http://www.uccee.org/AssessCDMAfrica/cdmafrica.htm): Contains papers and proceedings from a workshop held in Accra, Ghana, 21–24 September 1998, as part of a series of meetings promoted by the International Energy Agency (IEA) and the United Nations Environmental Program (UNEP). The aim of the workshop was to facilitate the engagement of African governments in the negotiation over the structure of the CDM.

Climate Change Impacts on the United States (http://www.gcrio.org/NationalAssessment/): The U.S. Global Change Research Program (USGCRP) established this national assessment in order to analyze and evaluate what is known about the potential consequences of climate variability and change for the United States.

Energy Information Administration Greenhouse Gas Emissions and Climate Change Publications (http://www.eia.doe.gov/env/ghg.html): Lots of good information on current and projected future greenhouse gas emissions.

EPA's Global Warming Internet Site (http://www.epa.gov/globalwarming/index.html): Comprehensive information on greenhouse gases and global climate change.

Financing Sustainable Development with the Clean Development Mechanism (http://www.wri.org/wri/cdm/nsflows_1.html): A technical report dated March 2000 by the World Resources Institute, with chapters on greenhouse gas trends in Brazil, China, and India.

Hadley Center for Climate Prediction and Research (http://www.meto.govt.uk/sec5/sec5pg1.html): The Hadley Center is jointly funded by the United Kingdom Department of the Environment and the United Kingdom Meteorological Office. The main objective of the Hadley Center is to provide an authoritative, up-to-date assessment of both natural and man-made climate change.

Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity (http://www.eia.doe.gov/oiaf/kyoto/kyotorpt.html): Comprehensive 1998 economic analysis of the costs of complying with the Kyoto Protocol, sponsored by the U.S. Energy Information Administration.

Intergovernmental Panel on Climate Change (http://www.ipcc.ch/): Learn about the latest consensus information on the status of greenhouse gas emissions, global climate change, and international policy responses.

Introduction to the Economics of Climate Change Policy (http://www.pewclimate.org/projects/econ_introduction.html): On-line report by John Weyant of Stanford University, prepared for the Pew Center on Global Climate.

Resources for the Future's Climate Economics and Policy Program (http://www.rff.org/misc_docs/climate_program.htm): This nonpartisan environmental think-tank established a Climate Economics and Policy Program to study the many different aspects of climate change, including energy markets, water and forest resource management, air pollution, environmental regulation, and sustainable development.

The Heat Is On (http://www.heatisonline.org/main.cfm): Internet site based on Pulitzer Prize–winning investigative reporter Ross Gelbspan's book on greenhouse gas emissions and global climate change.

United Nations Framework Convention on Climate Change (http://www.unfccc.de/): Comprehensive information on the UNFCCC, the Kyoto Protocol, and other aspects of coordinated international action on the control of greenhouse gas emissions.

Weathervane: A Digital Forum on Global Climate Policy (http://www.weathervane.rff.org/): Review the major issues in the climate change debate.

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Part III

Issues in the Economics of A More Sustainable Society

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11

Introduction to the Sustainability Perspective

Introduction

There is a growing awareness of the increasingly sharp demands that human societies place on their economies and their natural environment, and of the corrosion of many social and political institutions. Many also recognize that the imperatives of economic vitality, ecological health, and sociopolitical democracy are interdependent. *Sustainability* represents a vision of the future whose roots can be traced back to a variety of primary origins, including the Iroquois Confederation, which developed a standard of judging decisions based on the well-being of tribal people seven generations into the future. The sustainability movement calls for a more sophisticated and inclusive view of economic development and well-being that explicitly takes into account ecological health, natural resource stocks, vibrant and just communities, and democratic process. Sustainability has come to mean different things to different people, and by encompassing so many things, there is the potential for its meaning to dissipate or to become appropriated. We will develop a definition of sustainability in this chapter that can be used as a standard for evaluating social, economic, and environmental policies.

Daly and Cobb (1989) draw upon Aristotle's distinction between *chrematistics* and *oikonomia* to illustrate the difference between the mainstream of contemporary economic thought and the emerging sustainability economics. *Chrematistics* can be thought of as the process of managing economic affairs in such a way as to maximize the value of the decision maker's financial wealth, as measured in money. *Oikonomia* refers to household management, which in Greek times included a broad array of activities, a relatively larger number of people than we associate with modern households, and elements of a multigenerational perspective. Accordingly, Daly and Cobb argue that *oikonomia* differs from *chrematistics* in that (1) it takes a longer-term view, (2) it focuses attention on the well-being of the household community as opposed to a more individualistic perspective on financial wealth accumulation, and (3) it places a larger emphasis on use value, while *chrematistics* is more narrowly focused on money exchange values. Thus, *oikonomia* emphasizes the broader focus and longer time horizon that is more consistent with the sustainability perspective than is the prevailing economic focus on financial wealth, which is embodied in the concept of *chrematistics*.

Ecologists, environmental ethicists, and others argue that a sustainable society is premised on the integrity of the ecosystems that provide the basis for life on Earth. As we shall see in chapter 12, ecologists are not particularly sanguine with regard to the ability of human-made capital to substitute for natural capital (for example, that the loss of natural wetlands can be mitigated by constructed wetlands). According to this view, the path to sustainability requires restoration and preservation of the stocks of natural capital embodied in Earth's ecosystems. Economists and other social scientists acknowledge the central role of ecosystem integrity, but argue that sustainability also requires democratic process and empowerment, and a vital economy to provide economic security and meaningful work opportunities and to promote resource-efficient technologies.

According to this argument, restoration and preservation of natural capital stocks will not be assured until economic systems are put into place that address the basic human needs of the world's poor. And these sort of economic systems in turn require democratic process and empowerment so that all people have access to education, justice, a voice in governance, property ownership, and meaningful work opportunities. Sustainability encompasses both an ethic and a set of technical processes that relate ecological health and human well-being to an interdependent array of economic, sociopolitical, and environmental/ecological systems. In fact, as we will see below, sustainability occurs at the intersection of ecological integrity, economic vitality, and democratic systems and processes. The ethic of sustainability provides the common imperative and the shared values, and the technical processes provide the means of acting in a manner consistent with the sustainability ethic.

Modern international discussion of sustainability goes back at least to a United Nations Conference on the Human Environment, held in Stockholm in 1972, where the notion of *sustainable development* was put forward as a way of transforming conflicting objectives into complementary aspects of a common goal. Arising from this conference was the Stockholm Declaration, a set of principles that represented the beginning of international dialogue between rich and poor countries regarding the links among economic growth, declines in global common-pool resource systems such as the air, water, and oceans, and the well-being of people around the world.

In 1987, the World Commission on Environment and Development (the Brundtland Commission) published the book *Our Common Future*, which "defined sustainable development and called upon nations of the world to adopt the objective of sustainable development as the overriding goal and test of national policy and international cooperation" (Tokyo Declaration). The Brundtland Commission defined and framed the imperatives of sustainable development, and focused on the "interlocking crises" implied by the fundamental changes through which the planet is passing. As pointed out in *Our Common Future*, more than 80 percent of population growth is forecast to occur in the urban areas of the world's poorest countries. As these people strive for the same standard of living enjoyed by people in rich countries, will their industrialization doom the productive capacity of the world's biosphere? The problem of making the economy of an increasingly populous world environmentally sustainable is one of the central challenges that motivates the sustainability movement.

There are many definitions of sustainability and sustainable development. The World Commission on Environment and Development (the Brundtland Commission) provided the following definition of sustainable development in 1987:

> Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

While this is a very broad definition, the Brundtland Commission envisioned two key concepts associated with sustainable development. The first concept was that of *needs*—in particular, the essential needs of the world's poor, which was seen as having overriding priority. The second concept was the idea of *limits* on the ability of the environment to meet present and future needs. The Brundtland Commission identified seven strategic imperatives for sustainable development:

- Reviving growth.
- Changing the quality of growth.
- Meeting essential needs for jobs, food, energy, water, and sanitation.
- Ensuring a sustainable level of population.

- Conserving and enhancing the resource base.
- Reorienting technology and managing risk.
- Merging environment and economics in decision making.

The Brundtland Commission saw sustainable development as a process of change rather than as a fixed state of harmony. Therefore, the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made in a manner that is consistent with both future and present needs. The Brundtland Commission's view of sustainable development was centered on promoting more appropriate and equitably distributed economic growth, and the imperatives of ecological integrity and democratic systems and processes did not play as prominent a role.

At the 1992 United Nations Conference on Environment and Development (the Earth Summit) in Rio de Janeiro, Brazil, representatives from governments and nongovernmental organizations (NGOs) developed the Rio Declaration on Environment and Development, also known as the Earth Charter. In its original form the "Earth Charter" contained 27 principles covering a broad array of economic, social, and environmental issues. According to the 1992 Earth Charter, environmental protection constitutes an integral part of the development process and cannot be considered in isolation from it (principle 4), and countries must enact effective environmental legislation (principle 11). Moreover, principle 7 states that countries shall cooperate in a spirit of global partnership to conserve, protect, and restore the health and integrity of Earth's ecosystem. The 1992 Earth Charter recognizes the importance of economics in sustainable development. It affirms the right of development (principle 3), the essential need to alleviate poverty (principle 5), the imperative of reducing and eliminating unsustainable patterns of production and consumption (principle 8), technology transfer (principle 9), and the promotion of a supportive and open international economic system that would lead to economic growth and sustainable development in all countries (principle 12).

The 1992 Earth Charter also addresses empowerment and democratic principles. For example, principle 10 states that environmental issues are best handled with the participation of all concerned citizens. Moreover, individuals are to have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in decision-making processes. States shall facilitate and encourage public awareness and participation by making information widely available. Effective access to judicial and administrative proceedings, including redress and remedy, shall be provided. The 1992 Earth Charter recognizes the imperatives of empowering women and indigenous peoples. Principle 20 states that women have a vital role in environmental management and development, and that their full participation is therefore essential to achieve sustainable development. Likewise, principle 22 states that countries should recognize and duly support the identity, culture, and interests of indigenous peoples, and enable their effective participation in the achievement of sustainable development.

Representatives from governments and NGOs were unsuccessful in securing adoption of the Earth Charter during the Rio Earth Summit in 1992. The Earth Charter Initiative was created by the Earth Council and Green Cross International in 1994, and an Earth Charter Commission was formed in 1997 to oversee the drafting of a revised Earth Charter. At the conclusion of the Rio+5 Forum in Rio de Janeiro in 1997, the Earth Charter Commission issued the Benchmark Draft Earth Charter. After considerable feedback a second Benchmark Draft was issued in 1999, and a final version was issued in 2000. The 2000 Earth Charter has 16 main principles, various supporting principles, and a conclusion. The principles are divided into four parts: (1) Respect and care for the community of life, (2) ecological integrity, (3) social and economic justice, and (4) democracy, nonviolence, and peace. The Earth Charter Initiative offers the following definition of sustainable development on their Internet site (http://www.earthcharter.org/):

> The goal of sustainable development is full human development and ecological protection. The Earth Charter recognizes that humanity's environmental, economic, social, cultural, ethical, and spiritual problems and aspirations are interconnected. It affirms the need for holistic thinking and collaborative, integrated problem solving. Sustainable development requires such an approach. It is about freedom, justice, participation, and peace as well as environmental protection and economic well-being.

In 1995, the World Summit for Social Development produced a declaration and program of action that addressed defining and articulating a vision of sustainable development. The authors of the declaration and program of action articulated a deep conviction that economic development, social development, and environmental protection are interdependent and mutually reinforcing components of sustainable development, which is the framework for efforts to achieve a higher quality of life for all people. They argued that equitable social development recognizes that empowering the poor to utilize environmental resources sustainably is a necessary foundation for sustainable development. Finally, the authors of the declaration and program of action argued that broad-based and sustained economic growth in the context of sustainable development is necessary to sustain social development and social justice.

Multilateral doctrines such as the Brundtland Commission Report and the

Earth Charter are useful because they encompass the values and political interests of both high-income industrialized countries and lower-income countries. A more local and applied perspective on sustainability is provided by what is known as *conservation-based development,* which refers to programs and policies that help entrepreneurs succeed in developing viable businesses that are environmentally sound and make a positive contribution to their local community. For example, Johnson (1997) surveyed a number of local conservation-based development efforts in the U.S. Pacific Northwest. By looking at both successful and unsuccessful conservation-based development projects, Johnson was able to develop some basic themes that serve as practical design principles.

- They engage residents at the local, community, or watershed level to *define and pursue a common vision* of long-term community, economic, and ecosystem health. In the process, they often help to reinvigorate local civic processes and build upon local knowledge and culture.
- They seek to *maintain and restore healthy ecosystems* upon which the community and economy rely. Often this involves building a better knowledge base by engaging citizens in developing and monitoring indicators of community, ecological, and economic well-being.
- They *develop economic opportunities* that provide for the needs of local residents while ensuring the long-term sustainability of the ecosystem upon which the community relies. (p. 14)

Johnson argues that analysis of conservation-based development projects identifies three key lessons. One lesson is the importance of trust and the ability of people from widely diverse backgrounds and interests to collaborate. Second is the importance of finding markets for niche value-added or sustainably harvested products. Third is the importance of addressing poverty and diversity, and expanding community-based development to include people of more diverse cultural and ethnic backgrounds.

The definition of sustainability that will be used in this textbook draws upon many of the sustainable development themes articulated in the Earth Charter, and on conservation-based development themes identified by Johnson (1997). The definition of sustainability was developed by Viederman (1996), and states that:

> Sustainability is a community's control and prudent use of all forms of capital—nature's capital, human capital, human-created capital, social capital, and cultural capital—to ensure, to the degree possible, that present and future generations can attain a high degree of economic security and achieve democracy while maintaining the integrity of the ecological systems upon which all life and production depends. (p. 46)

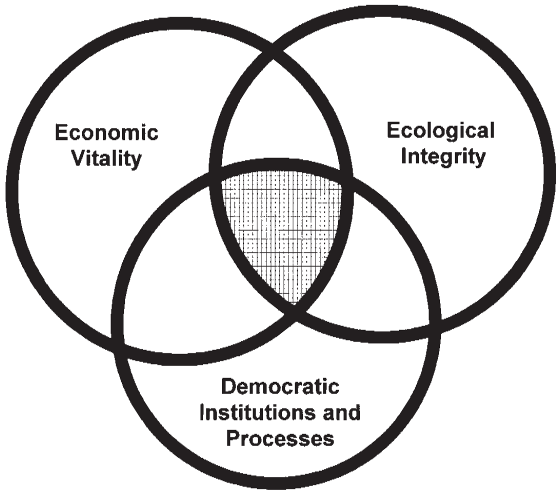
Viederman's (1996) definition begins with a discussion of the *five capitals* of sustainable development that shape, and are shaped by, human society. *Nature's capital* generates the flow of natural resources and other environmental benefits such as the rate at which human wastes can be assimilated. As Wackernagel and Rees (1997) observe, "Natural capital is not just an inventory of resources; it includes all those components of the ecosphere, and the structural relationships among them, whose organizational integrity is essential for the continuous self-production of the system itself" (p. 4). Costanza et al. (1997) and Daily (1997) argue that the various forms of *ecosystem services* such as climate regulation, soil formation, nutrient cycling, habitat, erosion control, and recreation are the benefits that flow from the stock of functional ecosystems that are an element of natural capital.

Human capital is another term for the knowledge, skills, and capabilities of people that can be deployed to create a flow of useful work for community and economy. *Created capital* is comprised of the technologies, productive facilities, and inventory of products that economists traditionally think of as "capital stock." *Social capital,* as the concept is used by sociologist James Coleman and political scientist Robert Putnam, refers to the stock of "civic virtues" and networks of civic engagement, involvement, reciprocity norms, and trust essential to democratic communities. For example, Putnam argues that in Italy social capital was essential to the functioning of markets and government in the *comuni* of medieval Pisa, Siena, Lucca, and Florence. Social capital is sometimes measured through participation rates in voluntary service groups such as PTA, unions, service clubs, and town hall meetings.

Finally, *cultural capital* refers to the body of knowledge, stories, visions, and myths shared by people that provide the framework for how individuals view the world and their proper role in it. Of the five capitals, cultural capital is probably the most difficult to grasp. One example of cultural capital might be the stock of traditional knowledge regarding the use of medicinal plants by Native Americans.

It should also be noted that Viederman's definition focuses attention on *community* rather than the individual. Private property regimes and market systems of allocation rest on an ethical foundation of individualism, which states that all values, rights, and duties originate in individuals and not in society as a whole. In contrast, the sustainability ethic holds the interdependent health and well-being of human communities and Earth's ecology over time as the basis of value. Viederman's definition ends by providing guidance for how society should deploy the various forms of capital at its disposal. The *three pillars* of sustainability offered by Viederman (economy, democratic process, ecology) are widely accepted as the central elements of a sustainable society and are illustrated in Figure 11.1.

Figure 11.1 **The Three Pillars of Sustainability**



In an earlier work, Viederman (1993) emphasized that sustainability is both an ethical standard and a technological, economic, and political problem to resolve. Building on this notion, Proops et al. (1996) argue that, while sustainability is often seen as a scientific problem for which technical solutions can be developed, more important is the development of an ethic "to formulate the goals, the social will to achieve these goals, and the maturity of judgement to realize the goals" (p. 133). To do so requires a broad consensus in society that sustainability is something that *should* be achieved. Proops and colleagues also argue that sustainability is not something to be achieved but a constant process.

One of the challenges associated with learning about sustainability and developing specific policies is the presence of rigid disciplinary boundaries, which tend to promote rivalries and limit cooperation. The discipline of ecological economics has recently organized itself around the integration of ecology (nature's household) with economics (humankind's household), an integration that is central to the concept of a sustainable society. The journal *Ecological Economics* states in its aim and scope, for example, that "this integration is necessary because conceptual and professional isolation have led to economic and environmental policies that are mutually destructive." It is likely that these boundaries were a necessary part of developing a set of "best methods" for isolating, analyzing, and ultimately understanding the economic, ecological, sociological, or political elements of the world. The argument from the sustainability movement is that these best methods must be integrated now that we recognize the inherent interdependencies across these disciplines. There is a natural hesitancy on the part of some economists, ecologists, sociologists, and other experts in various disciplines to overcome their differences in terminology, analytical methods, and outlook.

For example, Dasgupta and Maler (1996) point out that while it is self-evident that poor countries depend on the integrity of their environmental and natural resources—soil, forests, animals, and fisheries—for 50 years economic development models have largely ignored the health and integrity of environmental and natural resources as an element of successful development. Similarly, the discipline of environmental economics has largely ignored issues concerning poverty and its links to environmental quality. As the International Institute for Sustainable Development (IISD) has stated, the economics of a sustainable society "occurs at the intersection, or balancing, of three global imperatives: environmental integrity, economic efficiency, and the well-being of people [and community]" (IISD Internet site).

Summary

- The economics of a sustainable society "occurs at the intersection, or balancing, of three global imperatives: environmental integrity, economic efficiency, and the well-being of people [and community]." Viederman (1996) has defined sustainability as being a "community's control and prudent use of" the *five capitals*—natural, human, human-made, social, and cultural—"to ensure, to the degree possible, that present and future generations can attain a high degree of economic security and achieve democracy while maintaining the integrity of the ecological systems upon which all life and production depends" (the *three pillars*).
- Ecologists, environmental ethicists, and others argue that a sustainable society is premised on the integrity of the ecosystem. Ecologists do not see the potential for substitutability between important life-support elements of the ecosystem and human or human-made capital. From this perspective, one can argue that sustaining the integrity of the remaining stocks of natural capital embodied in Earth's ecosystems is the path to sustainability.
- Social scientists and economists acknowledge the central role of ecosystem integrity, but they argue that sustainability also requires democratic process and empowerment to allow people to make good decisions, and a vital economy to provide economic security. Moreover, most economists to varying degrees argue that some forms of human-made capital can substitute for declining stocks of natural capital and focus on maintaining human well-being as the path to sustainability.

- *Sustainability* is such an encompassing term that it easily loses its meaning. It includes both a process of development, an ethical and a policy standard, and a set of technical processes that relate ecological health and human well-being to an interdependent array of economic, sociopolitical, and environmental/ecological systems.
- A central issue associated with sustainability has to do with the proper way of guiding and measuring the performance of development. As we shall see in chapter 13, there are competing theories for what sustainable development means, and by implication, what policies are consistent with moving us closer to a sustainable society.

Review Questions and Problems

1. Go back to chapter 6 and review benefit/cost analysis and the dynamic efficiency standard that is implied by such an analysis. Can benefit/cost analysis and dynamic efficiency be made consistent with a sustainability standard? If so, how might this affect the appropriate choice of discount rate and the sort of screens that might be applied to various projects that could eliminate projects or policies that generate current benefits at the cost of future generations?
2. Contrast the focus of sustainability on community and intergenerational equity with the individualistic focus of contemporary Western society. Explain why the greatest challenge of sustainability might involve human values and attitudes rather than the development of policies and technologies.
3. Access the Sustainable Development on Campus Internet site maintained by the International Institute for Sustainable Development (http://iisd1.iisd.ca/educate/default.htm). Form a group and develop a proposal for greening your college or university campus.
4. As international statements, the Brundtland Commission report and the Earth Charter reflect the interests of both high-income industrialized countries and lower-income countries. Access the 1992 Earth Charter on the Internet (http://sedac.ciesin.org/pidb/texts/rio.declaration.1992.html). Review the principles and then list what you believe were the priorities of the high-income industrialized countries, and what you believe were the priorities of the lower-income countries. Identify possible conflicts between these lists of priorities that might imperil sustainable development initiatives.

Internet Links

Earth Charter 2000 (http://www.earthcharter.org/draft/charter.htm): The March 2000 draft of the Earth Charter is derived from the original Earth Summit in 1992.

Earth Charter Initiative (http://www.earthcharter.org/): An international group that promotes the Earth Charter.

Earth Council (http://www.ecouncil.ac.cr/): The Earth Council is an international nongovernmental organization (NGO) that was created in September 1992 to promote and advance the implementation of the Earth Summit agreements.

International Institute for Sustainable Development (http://iisd1.iisd.ca/): Ever since its incorporation in 1990, IISD has worked to help decision makers understand the principles of sustainable development and how to put them into practice. This site contains an enormous volume of useful information.

Rio Declaration on Environment and Development (Earth Charter) (http://sedac.ciesin.org/pidb/texts/rio.declaration.1992.html): Read the original 1992 Rio Declaration on Environment and Development.

SD Gateway (http://sdgateway.net/): The SD Gateway integrates the online information developed by members of the Sustainable Development Communications Network. They offer more than 1,200 online documents related to sustainable development, a calendar of events, a job bank, the Sustainability Web Ring, a roster of mailing lists (listservs), and news sites dealing with sustainable development.

Sustainable Development on Campus (http://iisd1.iisd.ca/educate/default.htm): IISD Internet site provides tools for making campuses more sustainable.

The Prosperous Community: Social Capital and Public Life (http://www.prospect.org/archives/13/13putn.html): Learn more about the value of social capital in this spring 1993 article by Robert Putnam published in the *American Prospect*.

Worldwatch Institute (http://www.worldwatch.org/): The Worldwatch Institute is dedicated to fostering the evolution of an environmentally sustainable society—one in which human needs are met in ways that do not threaten the health of the natural environment or the prospects of future generations. The Institute seeks to achieve this goal through the conduct of interdisciplinary nonpartisan research on emerging global environmental issues, the results of which are widely disseminated throughout the world.

References and Further Reading

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12

Recognizing Interdependencies and Thinking Long Term

Introduction

Sustainability is characterized by a recognition of the interdependencies linking economy, sociopolitical conditions, culture, technology, and the health of ecosystems. But what specific factors contribute to the sustainability of human society over the long term? This chapter will highlight a number of the more prominent factors and describe their relationship to the three pillars of sustainability. Sustainability is also characterized by a long-term perspective. In the second part of this chapter, we will discuss the challenge of making sustainable policy that is also dynamically efficient.

Recognizing Interdependencies

Moving toward a more sustainable society requires a recognition of interdependencies. These interdependencies are numerous and complex. For example, as discussed below, there has been a common pattern of industrialization around the world that has fundamentally changed the way people live and interact with the natural environment. Industrialized societies may be able to move toward increased sustainability by developing policies that affect incomes, education and empowerment, the terms of international trade, population growth, and taxation. Thus, it is important to understand the interdependencies that link these factors to a more sustainable society. For example, what is the relationship between income and environmental degradation? Is there a linkage between the education and empowerment of women, and population growth rates? International trade increases incomes, but how are those income gains distributed? How does an increasingly international pattern of trade affect the empowerment of local communities and the quality of the environment? What socioeconomic factors affect population growth rates, and how does this growth affect the integrity of ecosystems? How does a country's tax structure affect resource use and pollution? We shall survey these issues below.

The Industrial Revolution and the Agrarian Transition

The theory of path dependence suggests that where we are today, and where we are going to be in the future, can be explained in part by the particular series of events that make up our history. From this perspective, the human world is where it is today in large part because of our common experience with the industrialization process that transformed the way people live and relate to the world around them.

Prior to the Industrial Revolution, traditional agriculture was small in scale and labor intensive. Both Mahatma Gandhi and Thomas Jefferson saw small-scale, traditional agriculture as being at the center of healthy and thriving local communities. As economies industrialize and make greater and greater use of capital equipment, the scale economies that are inherent to capital lead to unit production costs that are lower for large farms than for small farms. Farmers and farm workers displaced by this process move on, frequently to urban centers, looking for work. This process leads to a small number of large-scale, highly capitalized farms. These large farms specialize rather than have both livestock and crops, so the old system of spreading manure from the livestock onto the cropped fields is replaced by chemical fertilizer, which is cheaper to apply. Food becomes relatively cheaper, and a large labor force is available for large-scale, low-wage manufacturing. In the United States, it took many years for workers to fully share in the gains created by the Industrial Revolution.

The process of assimilating displaced subsistence farmers in an industrialized urban society has not gone as well in many low-income countries. The results are seen in the squalor of growing shantytowns on the outskirts of many cities around the world. This is where the great majority of the world's population growth is predicted to occur. In particular, at the U.N.-sponsored Habitat II Summit in Istanbul in 1996, it was reported that 40 to 50 percent of the world's population lives in urban slums, and that people of the developing world continue to pour into these cities hoping to find a chance for a better life. By 2015, only one of the globe's ten largest cities (predicted to range in population from 19 million to 27.4 million people) will be in the rich countries of the developed world. The process of providing energy, shelter, and transportation to these rapidly growing urban centers will strain the resources of low-income countries. Lack of access to cleaner technologies may result in an industrialization path that, like that of the rich countries before them, involves a period of intense pollution, which makes sustainable development in the cities of developing countries a global problem.

Income, Poverty, and Economic Growth

From the material perspective of income and consumption, poverty occurs when people lack access to economic resources sufficient for them to meet their basic material needs, and are therefore physiologically deprived. But poverty also includes social deprivation, in which people are denied opportunities for improving their situation, and thus are robbed of dignity, confidence, and self-respect. The circumstances of those in poverty are often such that they have no choice but to live and work in the most polluted and degraded of environments. Moreover, those in poverty lack access to resources to meet their basic material needs, let alone to restore and conserve their natural environment. Poor communities are often politically disenfranchised, and are therefore also exposed to environmentally unjust policies.

A common international poverty threshold is an income equivalent of $1 in purchasing power per day, and based on this measure, the World Bank (1999) estimates that 1.5 billion people live in poverty. The World Bank reports that while per capita GDP in the richest one-third of the world's countries has approximately doubled since 1970, per capita GDP has remained largely unchanged in the other two-thirds of the world's countries. The *Human Development Report* (U.N. Development Program 2000) finds that about one-third of the world's nations experienced a drop in per capita GDP during the 1990s, including nearly one-half of those in sub-Saharan Africa and the majority of those in Eastern Europe. The disparity in incomes between wealthy and low-income nations continues to grow, implying that a relatively small percentage of the world's people and nations control most of the world's economic and natural resources. Adriaanse et al. (1997), for example, found that on average each person in an industrialized country consumes between 45 to 85 metric tons of natural resource throughput each year. Worldwatch Institute (2000) found that per capita paper use in industrial nations is nine times higher than in developing countries, and the number of cars per person is about 100 times higher in North America, Western Europe, and Japan than in India or China. Thus, chapter 4 of Agenda 21 from the Earth Summit concludes that high levels of consumption by the wealthy few results in excessive demands and unsustainable lifestyles among the richer segments, which place immense stress on the environment. The poorer segments, meanwhile, are unable to meet food, health care, shelter, and educational needs. Yet as the *Human Development Report* also observes, there is no automatic link between economic growth and progress in human development. Some countries have had fast growth and little improvement in human development, while others have had slow growth and yet more rapid improvements in human development. The *Human Development Report* argues that in order for economic growth to improve the well-being of all people, it must prevent losers from falling into abject poverty, and to create jobs, ensure wide participation, guard the environment for future generations, and guard cultural traditions.

One way to evaluate the association between income and more sustainable production technologies is to look at energy inputs and pollution emissions required to generate the equivalent of a dollar of GDP. Poorer countries that have relatively dirty industry are expected to have higher emissions per dollar equivalent of GDP. The World Bank (1995) reports that rich-country emissions of carbon dioxide per dollar of GDP have declined by nearly 50 percent from 1961 to 1991. Using this measure, the World Bank (WB) also reports that emissions rates by low-income countries in 1991 were approximately five times the level of rich countries, whereas those of middle-income countries were more than three times the level of rich countries. Similar patterns hold for energy consumption per dollar of GDP, where low- and middle-income countries consume almost four times the tons of oil equivalent per dollar of GDP as do rich countries. Moreover, the United Nations Commission on Sustainable Development (UNCSD) estimated that economic restructuring has led to a 30 to 40 percent reduction in many pollutants in Eastern European countries transitioning from Soviet-style economies. Thus, rich countries with high consumption levels also have relatively more resource-efficient production technologies. For example, while the United States emits 24 times the carbon dioxide per person as does India (an issue of sustainable consumption), the United States emits less than one-third as much per dollar equivalent of GDP (an issue of sustainable production).

Among the world's poorest countries, increased income is needed for those basic requirements that people in industrialized nations often take for granted: sanitation and water treatment, food storage, remediation of gross pollution problems, and fuel for heating and cooking. With water, for example, the basic need is to separate and properly treat drinking/cleaning water and wastewater. The World Bank (1992) estimated that 1 billion people were without access to safe drinking water, and nearly 2 billion did not have access to adequate sanitation. The World Bank (1993) measured the present value of future years of disability-free life lost due to premature death or to disability from air or water pollution in a given year. It found that people in very low-income regions suffer much higher rates of illness and disabilities caused by bad air and water. The rate per 1,000 people in sub-Saharan Africa was 120, approximately 70 for India, more than 60 for the Middle East, approximately 15 for China, and about 7 for "established market economies." In countries with more than 20 percent of their population subsisting on $1 per day or less, at least 40 percent of children are affected by stunted growth, and people subsist on about half the amount of fresh water per capita as in richer countries (World Bank 1994). Half of the world's poor live in ecologically fragile rural areas and rely almost entirely on natural resources for day-to-day survival. Under these conditions, food insecurity leads to the development of agriculture on unsuitable terrain such as steep, erosion-prone slopes or nutrient-poor rainforest floors (Barrett 1996).

People who have inadequate food, water, and shelter for themselves and their children, and people, especially children, suffering from waterborne diseases and malnutrition, are under tremendous pressure to deal with today's crisis and may have to choose between protecting natural resources for the future and keeping themselves and their children fed today. Very poor regions and countries are the least resilient to stresses and shocks such as droughts, population booms, and political instabilities. When poor people live in ecologically fragile areas, the response to shocks may be to intensify deforestation, rangeland degradation, or displacement of wildlife habitat. In a very stark sense, the high cost of energy-efficient and cleaner technologies, and the opportunity cost of protecting biodiversity and wildlife habitat, may make important elements of protection and conservation a luxury that only the rich countries can afford.

Population growth in lower-income countries has increased the scarcity of resources such as firewood for heating and cooking food, clean water for drinking and cleaning, fertile ground for raising food, and habitat for fishery resources. Industrialized nations have developed substitutes and energy-efficient technologies for overcoming the scarcity of these resources, yet these substitutes are costly. For example, pipeline infrastructure can be used to deliver natural gas and water to households, thereby reducing pressure on forests, freeing up labor for more productive activities, and improving sanitation. By the same token, relatively simple alternative energy technology such as solar ovens allows an even more complete move toward sustainability. The problem is that people in low-income countries may be priced out of the market for more sustainable production technologies.

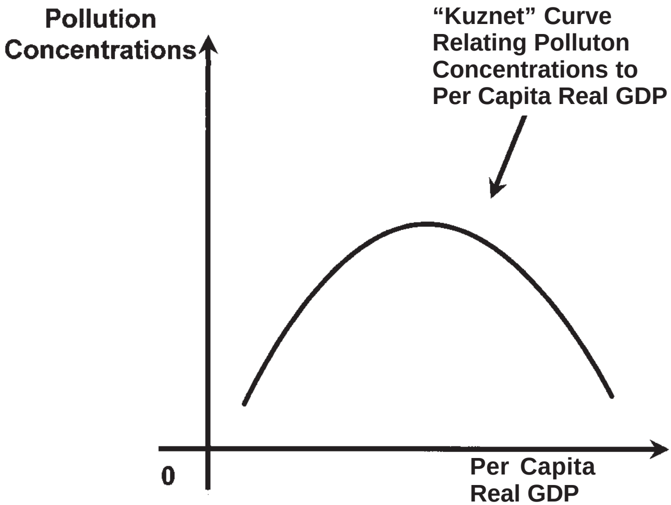
A number of economic studies have found evidence for an inverted-U-shaped relationship between the concentration of certain pollution emissions (sulfur dioxide, oxides of nitrogen, lead, particulates, carbon monoxide) and per capita real GDP (Selden and Song 1994; Grossman and Krueger 1993; Hettige, Lucas, and Wheeler 1992; World Bank 1995), as illustrated in Figure 12.1. This inverted-U relationship is similar to the "Kuznets curve" hypothesis that income inequality first rises, and then declines, with economic development. Thus, the inverted-U relationship between pollution concentrations and per capita real GDP is sometimes referred to as a type of pollution "Kuznets curve." The idea is that as very low-income countries industrialize, increased production and consumption are both initially fueled by burning coal and other relatively dirty fossil fuels. Thus, the world's worst urban air pollution occurs in low-income countries. As incomes rise, however, some of the wealth is used to buy a cleaner environment by switching to cleaner fuels like natural gas and to more energy-efficient technologies. This pattern would explain the difference in concentrations of atmospheric sulfur dioxide emissions between, say, a nonindustrialized country in comparison to China, and China in comparison to Germany.

An unfortunate implication of much of this empirical research is that nations such as China, India, and most countries in South America and Africa are on the left-hand curve of the inverted U, meaning that incremental increases in income will create *more* rather than less pollution in the near future. Not all economists accept the inverted-U relationship as a general metaphor for the relationship between income and sustainability. For example, in commenting on the inverted-U relationship, Nobel laureate Kenneth Arrow and colleagues (1996) observed: "While they do indicate that economic growth may be associated with improvements in some environmental indicators, they imply neither that economic growth is sufficient to induce environmental improvements in general, nor that the environmental effects of growth may be ignored, nor, indeed, that the Earth's resource base is capable of supporting indefinite economic growth. In fact, if this base were to be irreversibly degraded, economic activity itself could be at risk" (p. 106).

Arrow and colleagues (1996) go on to point out that the inverted-U relationship has not been shown to hold for accumulated stocks of waste or pollutants involving long-term or more dispersed costs (such as CO_2), for resource stocks, or for systemwide consequences (for example, reductions in one country pop up as increases elsewhere). Finally, Arrow et al. argue that most reductions in pollutants are attributable to local institutional reforms such as environmental regulations, market-based incentives, and empowerment to reduce environmental impacts.

Another argument linking income growth to sustainability comes from a World Bank (1995) report indicating that most rich countries have fossil-fuel taxes, which discourage fossil-fuel use, while lower-income countries actually subsidize such energy use. We will discuss this point in greater detail

Figure 12.1 **Inverted-U Relationship Between Pollution Concentrations and Per Capita Real GDP**



below. Yet another point in favor of the argument that economic growth is needed for low-income countries to become environmentally sustainable is that rising incomes tend to be associated with declining population growth rates, which is also explained in greater detail below.

To summarize, then, economic growth produces income that raises people out of poverty, and higher incomes are associated with lower fertility rates and the prevalence of cleaner and less resource-intensive production technologies. But there are strong counterarguments to the idea that higher incomes move us closer to a sustainable society. One could argue that it is the rich countries, after all, that consume the great majority of the world's resources and are responsible for a disproportionate percentage of the world's trash, toxic emissions, ozone-depleting chemicals, and greenhouse gases. For example, with 5 percent of the world's population, the United States generates 19 percent of the world's wastes and consumes 20 percent of the world's metals, 24 percent of its energy, and 25 percent of its fossil fuels. This rich-country consumption is linked through the market process to serf wages and dirty production technologies in the poor countries. The process of economic growth and rising consumption has been accompanied by the evolution of multinational corporations with fluid capital and enormous influence. These organizations dominate the world's marketplaces; they influence governments, own much of the news media, and mold values, behavior, and policy through advertising and political contributions. The combined sales of the world's largest 350 multinational corporations represent one-third of the industrialized world's economies. The 100 largest multinational corporations own $4 trillion in assets, yet one-half of these assets exist outside the corporation's country of origin, highlighting the growing problem of accountability.

As Ayres (1996) argues, "It is quite possible to have economic growth—in the sense of providing better *and more valuable* services to ultimate consumers—without necessarily consuming more physical resources" (p. 118), sometimes known as *throughput.* This is because ultimately, people are interested not in the volume of goods consumed but in the qualities and services that they provide. Costanza and Daly (1992) argue that the term *economic growth* should be used when throughput is increased, whereas the term *development* should be used when economic growth occurs as a consequence of increased resource and organizational efficiency that does not increase throughput. Ayres further observes that increasingly resource-efficient technologies allow for a de-linking of large elements of economic activity from energy and other materials, a process sometimes known as *dematerialization*, which has occurred to some extent with computer and telecommunications technologies. By the same token, policies that focus on economic growth, as measured by GDP, will not necessarily improve the well-being of people or lead to a more sustainable society. We will discuss the relationship between GDP and sustainable development in chapter 13.

Education, Empowerment, and Justice

Sustainability is not simply restricted to the relationship between economics and the environment. Just as important are a variety of social, cultural, and political empowerment issues. Failures of empowerment lead to dependency, exploitation, and a wide variety of other ills. Important areas for empowerment include recognizing the rights of communities to sustainably manage the local common-pool resources upon which they rely, and giving women access to education, employment, land ownership, and influence over policies that affect them.

One indicator of empowerment is the adoption of democratic institutions in government, and the World Bank (1999) reports that the number of democratically governed countries has grown steadily. Yet in many parts of the world, the empowerment of women remains largely unfulfilled. As of 1995, more than 60 percent of the world's poor were women, and growth in this poverty rate has been higher for women than for men. Approximately 66 percent of the world's illiterate are women and girls, up from 58 percent in 1960, and Worldwatch Institute (2000) reports that women account for only

13 percent of the representatives in national legislatures. Significant gaps continue to exist in school enrollments between boys and girls. Between 80 and 90 percent of the female workforce are not protected by labor laws. Women own less than 1 percent of the world's property. Women hold only a small fraction of the seats in the world's national congresses and parliaments. Women and children were 80 percent of the world's refugees and displaced peoples (Jazairy et al. 1992; Erlich et al. 1995; Mehra 1996).

The lack of educational access limits women's work productivity and ultimately their incomes. A particularly strong inverse relationship exists between education, work, reproductive decision-making opportunities available to women, and fertility rates. *The Economist* (2 September 1995) reported on studies indicating that one year of female schooling reduces fertility rates by between 5 and 10 percent. In addition, a simulation study indicated that, all else being equal, doubling female secondary school enrollments in 1975 would have reduced the average fertility rate in 1985 from 5.3 to 3.9 children, lowering the number of births by approximately 30 percent. As well as having fewer children, educated women are more likely to have better-fed, and therefore healthier, children—who will themselves be better educated, as indicated by evidence from Nicaragua, Pakistan, Vietnam, and Ivory Coast. In 1970, Thai women on average had 5 children; that number had fallen to 2.2 by 1995. During that same period, Erlich et al. (1995) report that literacy rates among Thai women increased from 72 to 90 percent.

Mehra (1996) reports that the majority of poor women in developing countries support their families through farming and the raising of livestock, and thus are at the heart of where new and more sustainable practices must be implemented. In many parts of Africa, women provide the majority of the labor for food production, which in many cases results in nearly one-half the cash-equivalent value of household income. Women play a central role in collecting livestock feed and water and in providing labor for gathering wood for fuel. Yet in many of these same countries, women are blocked from owning land and thus receive only a small fraction of development funds going to agriculture. By working land they do not own, women lack the incentive to make long-term investments that benefit the environment, such as the planting of trees. In fact, in some parts of Africa, Mehra (1996) reports that land tenure is linked to the planting of trees, and men prevent women from planting trees as a way to keep them from gaining land ownership and power. Moreover, women are frequently not given the same access to economic development and conservation resources. External aid organizations have in the past been unaware of the key role of women in agriculture and resource management, and so develop site-specific plans with men, with the result being misdesigned projects that omit those who are responsible for carrying them out.

Looking beyond the issue of gender, another manifestation of empowerment is the provision of secure land tenure to farmers. A lack of secure, long-term land tenure can reduce farmers' incentives to make beneficial long-term investments in the land that they work. For example, lack of secure land tenure in China has led to a reluctance by farmers to sink money and labor into land improvements such as terraces to limit erosion, because farmers fear that they may not be able to keep farming the land long enough to realize a return on their investment (Prosterman, Hanstad, and Ping 1996). Securing land tenure may involve recognizing, and returning to, locally devised systems of private and common property.

Exploitation, which is obviously inconsistent with sustainability, is more likely to result when there is a substantial asymmetry in local power and a failure to recognize local property rights regimes and the right to local self-governance. For example, local communities and tribespeople of Ogoniland in Nigeria have little control over the massive oil development and collateral environmental degradation from corporations such as Royal Dutch–Shell in partnership with the Nigerian government. Income from oil development enriches the military regime of Nigeria, which has executed a number of dissident Ogoni tribespeople protesting the environmental degradation, including activist Ken Saro-Wiwa. Similarly, native Papuans have suffered because of the huge Freeport mine, owned by RTZ-CRA, one of Britain's (and the world's) biggest mining groups, and Freeport-McMoRan, an American firm. In 1995, it is estimated that RTZ-CRA made pretax profits of $2.46 billion (*The Economist*, 20 July 1996). As reported in *World Press Review* (July 1996, pp. 14–17), this mine occupies four square miles and generates an estimated $390 million in royalties to the Suharto regime, which owns a 10 percent stake in the mine. Each day it is estimated that the Freeport mine dumps 132,000 tons of mine tailings in the Ajikwa River (an amount expected to rise to 210,000 tons) and destroys 15 square miles of riverine rainforest. Tribal leader Tom Beanal claims that the mine has destroyed the Ajikwa River fishery. The Amungme people receive no royalty income and are under pressure from the Indonesian military to leave their homeland near the mine and resettle.

Multinational corporations claim that if they did not do business with governments accused of extensive human rights and environmental abuses, others would, and those others would not have the same degree of ethical control. Moreover, multinational corporations might also argue that their presence generates income that will eventually raise local living standards. Both points can be argued, just as one could argue that these corporations could use their leverage to foster reforms and pressure the more repressive governments with which they do business.

Income inequality is both a cause and a manifestation of asymmetries in empowerment and educational access. According to the *Human Development Report* (UN Development Program 1994), in the early 1990s the wealthiest 20 percent of the world's population received 82.7 percent of the world's income, while the poorest 20 percent received only 1.4 percent. Moreover, this gap had doubled since 1960, when the richest 20 percent had only 30 times the income of the bottom 20 percent. Milanovic (1999) examined world income distribution using household survey data in 1988 and again in 1993, and found a sharp rise in world income inequality. Milanovic measured inequality using a Gini coefficient, where a value of 0 indicates perfect equality and a value of 1.0 total inequality. He found that the world Gini coefficient increased from 0.63 to 0.66, and that the increased inequality was mostly attributable to rising differences in average incomes across, rather than within, countries. According to the *Human Development Report* (UN Development Program 2000) the wealthiest 200 individuals in the world had a combined income of $1.135 trillion in 1999, up by nearly 9 percent from that of 1998, and approximately ten times the total income of the estimated 528 million residents of the world's lowest-income countries.

Countries with the most unequal distributions of income also tend to be relatively poor, an issue investigated by Simon Kuznets (1966). More recently, Persson and Tabellini (1994) studied 56 countries and found a strong negative relationship between income inequality and growth in per capita income, something they attributed to government policies that failed to protect individual rights, and appropriated the returns on effort and other investments. Similarly, World Bank researchers report that unequal distributions of assets such as land form an even greater impediment to economic growth (Deininger and Squire 1997). In many cases, a political/economic elite controls most of these countries' income-generating resources and so gets most of the income.

For example, *The Economist* (5 August 2000) reports that the Suharto family is alleged to have corruptly amassed a $45 billion fortune in Indonesia. Prior to his ouster, the children of President Suharto were reportedly involved in almost every aspect of Indonesia's economic life. When asked how Indonesia's economy is run, President Suharto reportedly replied, "My children are very good in business." Income inequality is not just a problem in the poor countries, however. The Organization for Economic Cooperation and Development (OECD) recently reported that the United States has the most unequal distribution of income among the rich countries. Obviously, one implication of income inequality is that information on average *per capita income* is not very descriptive of the conditions under which most people live.

Highly unequal distributions of income, and the mass poverty that goes with them, are difficult to reconcile with a sustainable society. Economic systems featuring highly unequal distributions of wealth and income frequently result in the political disenfranchisement of the poor, which is inconsistent with the requirement for democratic process in a sustainable society. In addition, most revolutions around the world have been reactions to extremely unequal distributions of wealth, political influence, and blocked access to wealth-generating resources. Countries with highly unequal distributions of income must spend substantial resources on building walled communities, prisons, and other defensive investments against crime and theft. Of course, no country has a perfectly equal distribution of income, nor would any country necessarily want to. There are two somewhat conflicting notions of fairness at work. One notion of fairness is that a person's income should match the value of the work he or she does, which naturally leads to some inequality, but provides desirable incentives. Another notion of fairness is that of fundamental human rights, from which one might argue that it is morally wrong for one person to be a billionaire while another starves in the street.

Government failure in providing education and opportunities to all people has led to the emergence of NGOs—nongovernmental organizations—to deal with rural development, small-farmer rights, urban service provision, and protection of natural resources. The NGOs include international development organizations (the International Monetary Fund [IMF], World Bank), human rights organizations (Amnesty International), environmental organizations (Greenpeace, the World Wildlife Fund [WWF]), unions, and so forth.

A remarkably successful form of empowerment is the provision of microscale loanable funds to help people living in poverty start small businesses. Traditional banks will not lend to people who do not own valuable assets that can be pledged to secure repayment, and *venture capitalists* (those who capitalize as entrepreneurs with funds from sources such as pension funds, university endowments, foundations, and wealthy individuals) rarely work with small or microscale entrepreneurs. A positive development in the area of women's empowerment and the alleviation of poverty is the creation of Bangladesh's Grameen Bank and similar organizations that specialize in microlending. In 1976, economist Muhammad Yunus went into the villages of Bangladesh to try to find out how the poor of Bangladesh could be helped. In one village, Yunus found 41 people engaged in activities such as making bamboo stools and earning wages of only 2 cents a day. What they lacked was the equivalent of $26 to capitalize small businesses that would make them entrepreneurs capable of earning substantially more money.

Yunus created the Grameen ("village") Bank to provide microloans to the most impoverished and oppressed villagers so they could set up their own small businesses to produce goods such as baskets, fishnets, and food. Most of the borrowers from Grameen Bank are women. Yunus found that women proved to be more disciplined and resourceful borrowers, were more reliable in repaying their loans, and could be counted on to share profits with their families (Counts 1996). These microloans have played a surprisingly central role in alleviating poverty. Approximately 98 percent of the loans have been repaid, a rate higher than for traditional banks in the area that lend to wealthier people. A key reason for this high repayment rate, and for the success of Grameen-style banking, is that individual loans are made in the context of a peer group or solidarity group. Each member of the solidarity group assumes responsibility for guaranteeing the repayment of loans extended to every other member (Stix 1997). The Grameen Bank has elevated an estimated 46 percent of its female borrowers above the poverty line and 34 percent of the others very close to the line. Among a control group of similar families that had not been capitalized by Grameen, only 4 percent were above the poverty line. Both Bornstein (1996) and Counts report that the Grameen Bank has been substantially more successful in combating poverty than traditional foreign aid or other antipoverty programs.

Grameen-style microbanking is rapidly growing, and there are microlending organizations in most countries around the world. Stix reports that as of 1996, there were nearly 250 microlending organizations in the United States alone, mostly made up of not-for-profit organizations, a figure that has more than doubled in four years. In some places, microlending has become a large-scale tool of economic development. For example, BancoSol of Bolivia has made nearly 72,000 microloans (averaging $661 each, with a 1996 default rate of 0.54 percent), making it the largest bank in Bolivia when measured in terms of numbers of customers (Stix 1997). The United Nations Development Program reported in 1994 that microlending schemes in India, the Philippines, the Dominican Republic, and Costa Rica raised average incomes of the poor who were participating in these programs by between 27 and 100 percent. A similar program among low-income African-American women in Chicago, called the Women's Self-Employment Project Full Circle Fund, has specialized in providing microloans for women to start very small enterprises. Mildred Leet began the organization Trickle Up, which makes microloans of $50 to $100 in Asia, Africa, Latin America, and the Caribbean Basin. Leet reports that, as with the Grameen Bank, many borrowers are women who could not otherwise find employment, and the microloans allowed these people to become entrepreneurs who produce fruit juices, ginger wine, cakes, dolls, and other crafts, and provided marketing and other assistance.

It is clear that Grameen-style microlending cannot function in a social and political vacuum—there must be substantial social capital within the solidarity group as well as sufficient business training and accountability among both borrowers and lenders. Moreover, microlending is not a panacea and should not be seen as a substitute for education and public health programs, among others. Performance up to now does suggest, however, that microlending is an important tool of more sustainable economic development.

International Trade

International trade and its relationship with sustainability is another contentious subject. The classical argument in favor of free and unimpeded international trade, which goes back to Adam Smith and David Ricardo, is that free trade allows for regions and countries to specialize in those activities that they do best. Specialization and trade creates material wealth, and increased international competition promotes innovation and reduces consumer prices. Free trade and investment can heighten exploitation, however, when governments engaged in trade, or the trade agreements they create, lack adequate democratic institutions and processes. For example, trade between wealthy and low-income nations can lead to a process whereby low-income countries with lax environmental laws, poor enforcement, or corrupt administration specialize in producing goods that are pollution-intensive or resource-intensive, and specialize in providing waste disposal services by accepting toxics and trash generated in wealthy countries. Trade agreements can also undermine local sovereignty and take away tools that can be used to assure compliance with labor and environmental standards when environmental or labor regulations are narrowly interpreted as trade barriers. And multinational corporations working in partnership with corrupt government authorities can construct environmentally damaging projects that displace local communities and create benefits that are narrowly focused on a political elite. We will discuss these and other issues below. In chapter 13, we will look at the mixed record of success with international development lending.

The Argument for International Trade

Adam Smith observed that because people (and regions) are particularly productive in some activities and less so in others, specialization and trade can increase the material welfare of the traders. To see this, consider the following simple example. Suppose that an island has a coastal zone rich in fish and marine resources, but poor in forest and agricultural products. Therefore, resources such as labor and capital that are applied to forestry or agricultural production on the coast come at a high opportunity cost in terms of lost fish production, as these resources can be more productively applied to fishing. Suppose that the island also has an interior that is rich in forest and agricultural products, but poor in fish and marine resources. Therefore, resources such as labor and capital that are applied to fish production in the interior come at a high opportunity cost, for they can be more productively applied to forestry and agriculture.

Suppose further that each zone is a separate country, and that fish, forest, and agricultural resources are required for food, shelter, and other basic needs. In the absence of trade, forest and agricultural products will be very expensive in the coastal country owing to their relative scarcity and high opportunity cost. Similarly, fish will be very expensive in the interior country owing to the high opportunity cost of its production. Because forest and agricultural product prices are considerably higher on the coast than in the interior, entrepreneurs will recognize that an *arbitrage opportunity* exists, and will therefore export these products to the coast where they are more valuable. An "arbitrage opportunity" exists when there is a difference in prices in different markets that cannot be entirely accounted for owing to differences in shipping and transaction costs, and which therefore promotes trade.

Likewise, because fish prices are considerably higher in the interior than on the coast, entrepreneurs will have an incentive to export these products to the market where they are more valuable. Bargaining and trade between the coast and the interior will cause the price of fish, forestry, and agricultural products to equilibrate across the two countries. With free trade, the coastal people can specialize in fishing, and they can eliminate their costly and less productive domestic forestry and agriculture industries. By the same token, the people of the interior can specialize in forestry and agriculture and eliminate their costly and less productive domestic fishing industry. With the same labor and capital resources, free trade allows an increase in total production. Or if maintenance of a steady-state economy is desirable, then less labor is needed, allowing perhaps for the development of the arts, education, and leisure.

This example illustrates the *Law of Comparative Advantage*, which states that total material wealth can be increased when goods and services are produced by the party with the lowest opportunity cost. Because the coastal country produces fish at a low opportunity cost relative to the inland country, the coastal country should specialize in fish production. Their low opportunity cost gives them a comparative advantage in producing fish relative to the inland country. Likewise, because the inland country produces forest and agricultural products at a low opportunity cost relative to the coastal country, the inland country should specialize in forestry and agriculture. Because the countries specialize, they must trade in order to have all the goods and services that they need and desire. As each product is produced at the lowest possible opportunity cost, resources are efficiently allocated in the sense that production is maximized, and material wealth is increased. The notion of comparative advantage as the basis for specialization and trade is usually credited to classical economist David Ricardo, with some of the basic arguments formulated by his predecessor, Adam Smith.

Free international trade may move us closer to a sustainable society for several reasons listed below:

- By increasing wealth, free trade can work to raise people out of poverty and improve their material standard of living.
- As wealth increases, poorer countries increasingly can afford costly but cleaner energy technologies.
- Trade exposes people to different cultures and can foster increased understanding and tolerance of diversity.

Of course, concerns regarding self-sufficiency, the cost of transporting goods, and cultural and religious incompatibilities can reduce the gains from free trade. Moreover, in the example given above, free trade displaced those coastal people engaged in relatively unproductive forestry and agriculture and those people from the interior who specialized in fishing. There is also no guarantee that the gains from free trade will be distributed equitably within either country. Nevertheless, most human cultures over thousands of years have engaged in some degree of trade, driven by the basic incentive to exploit arbitrage opportunities and improve material standards of living. Attempts at heavily regulating or eliminating trade will usually result in the development of black markets. As economist Paul Krugman has stated, "[i]f there were an Economist's Creed it would surely contain the affirmations, 'I believe in the Principle of Comparative Advantage,' and 'I believe in free trade' " (1987, p. 131).

The Argument Against International Trade

The recent increase in capital mobility can lead to rapid shifts in comparative advantage. To see this, suppose that country A has developed an automobile industry, while country B has developed a textile industry. Once these industries are in place, we would naturally expect that international trade in cars and clothes would proceed along the same lines as in the island example given above. But what prevents business people in country B from moving textile mills to country A to avoid shipping expenses, or perhaps to exploit lower labor costs? While such a move improves profit and reduces consumer prices, it also can lead to considerable labor displacement and even destroy local mill-dependent economies. With capital mobility and free trade, countries with low labor or other input costs (for example, with few pollution-control or other regulatory requirements) will tend to attract capital, which will then tend to equilibrate wage rates and regulations between the high- and low-wage countries. Labor and environmental groups in high-wage and high-standard nations see this as a "race to the bottom." These effects are manifestations of the *factor price equalization theorem* developed by Ohlin (1933).

Daly and Cobb (1989) argued that because of capital mobility, free trade tends to erode livable wages, the bargaining power of unions, and environmental and other standards of communities. In a free-trade regime with competitive labor markets, people are paid based on their productivity relative to the productivity of workers around the world. Thus, to be paid substantially more than a worker in India, China, Ethiopia, or Mexico, a domestic worker would have to be substantially more productive. A manufacturing worker whose hourly compensation costs a firm $15.00, would have to be approximately an order of magnitude more productive than a Mexican worker whose hourly compensation costs a firm $1.50. As a consequence, the wage impacts of rapid population growth in developing countries can quickly be transmitted around the globe. Education and training that enhances worker productivity is essential to maintaining high wages under free trade and capital mobility. Another problem can occur when *economies of scale in production* (unit costs that fall as the scale of production increases) are combined with capital mobility. Large production facilities can use the threat of leaving and taking jobs away to squeeze regulatory and tax concessions from local communities.

As mentioned earlier in the chapter, free trade and investment can heighten exploitation, however, when governments engaged in trade, or the trade agreements they create lack adequate democratic institutions and processes. Chichilnisky (1994), for example, models North–South trade between a high-income country with well-defined and enforced property rights to environmental resources and a low-income country with poorly defined and enforced property rights. The difference in the level of property rights enforcement is sufficient by itself to motivate bilateral trade, because the environmental resource is underpriced in the low-income country relative to the high-income country owing to the exhaustion of Hotelling rents (discussed in chapter 5). Chichilnisky shows that the "tragedy of the commons" effect in the low-income country is worsened by trade and transmitted to the entire world economy. Overproduction of the environmental resource in the low-income country is matched by overconsumption of the resource in the high-income country. Thus, it is not necessarily efficient for countries in the South to specialize in dirty, resource-extractive production.

Another argument that free international trade undermines sustainability is that it allows wealthier nations to export pollution-intensive and resource-intensive production processes to developing nations. Saint-Paul (1995) raises this point in his criticism of the work of Grossman and Krueger, arguing that the inverted-U-shaped relationship could also represent a type of international specialization that occurs as a consequence of free international trade;

namely, that rich countries will try to import pollution-intensive goods rather than produce them. There has not been much evidence that firms are systematically shifting their dirtier production facilities to so-called pollution havens for the primary purpose of avoiding cleanup costs; as pointed out earlier in the book, plant moves are explained in larger part by labor-intensive industry's seeking wage savings in developing countries.

A related problem is that of rich countries exporting toxic wastes and trash. Poor people living in low-income countries (or regions of an otherwise wealthy country) who are in desperate need of income are more willing to accept toxic waste and garbage dumping than are wealthy people. The U.S. Supreme Court has stated a number of times that garbage is in fact a product whose interstate trade cannot be interfered with by individual state law. Hence, wealthy communities export their trash by truck, barge, and rail to some of the poorest counties and Native American reservations in the United States. A parallel problem exists in an international trade context. The ability of wealthy communities or countries to find least-cost dumping facilities for their waste serves to weaken their incentive to reduce the flow of this waste, and so undercuts attempts at minimizing wasteful packaging and the generation of toxic wastes.

Yet another problem with international trade liberalization derives from the way we have structured international trade agreements. The General Agreement on Tariffs and Trade (GATT), forged in concert with the IMF and the WB at the Bretton Woods Conference in 1947, and renegotiated in Punta del Este, Uruguay, in 1986, may threaten the integrity of local, national, and international environmental improvement efforts. GATT requires signatory countries to follow the principles of multilaterialism (trade is governed by international rules) and "nondiscrimination." Nondiscrimination requires that foreign firms be treated the same way as domestic firms ("national treatment"), and that firms from different countries also be treated the same ("most favored nation"). Thus, if an exporter in country A cannot sell its *existing product* in country B because country B has environmental laws that constrain how the product is made or packaged, the exporter (or country A) can file a complaint with the World Trade Organization (WTO) that country B has a "nontariff trade barrier" that restricts free trade. It is then possible that the WTO will impose reciprocal trade and other sanctions on country B.

The WTO was formed in 1994 as a successor to GATT, and the primary activities of the WTO are in resolving international trade disputes. The WTO decisions are binding on the 125 member countries. Article XX of GATT states that GATT shall not be construed as preventing the adoption or enforcement by any contracting party of measures (1) necessary to protect human, animal, or plant life or health, or (2) relating to the conservation of exhaustible natural resources, if such measures are made effective in conjunction with restrictions on domestic production. Article XX has been the subject of a number of test cases having to do with disputes over environmental regulations as nontariff trade barriers. In most cases, the GATT or the WTO has found against the environmental regulations. For example, Mexico filed a trade complaint against the United States under GATT in 1991 over provisions of the Marine Mammal Protection Act, which requires the United States to ban imports of tuna from countries that could not prove that adequate dolphin protection measures were utilized. Two important issues emerged from this case. One issue was whether one country could tell another what its environmental regulations should be, and the other issue was whether trade rules allow bans or tariffs based on the method used to produce goods, rather than the quality of the goods themselves. The GATT panel said no to both questions. Based on this finding, domestic U.S. tuna fishers would be placed at a disadvantage over foreign fishers, and the United States would no longer have the sovereignty to limit imports produced in an unsustainable manner.

Another such case had to do with a complaint filed by Venezuela and Brazil against the United States. The charge was that U.S. regulations for evaluating a gasoline refiner's compliance with the Clean Air Act (CAA) of 1990 discriminated against foreign refiners. In particular, the EPA's "gasoline rule" allows domestic refiners to use an "individual baseline" to evaluate toxic and other pollution emission characteristics of its currently refined gasoline. In other words, if the refiner was producing gasoline prior to the CAA, then the refiner could evaluate its gasoline using an internal or individual baseline. The gasoline rule did not allow foreign refiners to use a similar individual baseline but instead required them to use a statutory baseline. After final appeals were heard in April 1996, the WTO found in favor of Venezuela and Brazil, stating that because "imported gasoline was effectively prevented from benefiting from as favorable sales conditions as were afforded domestic gasoline by an individual baseline tied to the producer of the product, imported gasoline was treated 'less favorably' than domestic gasoline" (WTO panel report on "United States—Standards for Reformulated and Conventional Gasoline" [WT/DS2/R]). Importantly, the WTO panel agreed that clean air is an exhaustible natural resource and so is covered under Article XX.

In another important case, in October 1996 a complaint was filed by India, Malaysia, Pakistan, the Philippines, and Thailand, [WT/DS58], challenging a U.S. ban on imports of shrimp caught without using turtle-excluding nets. Again the WTO found against the United States, arguing that the ban was unilateral and thus violated the doctrine of multilateralism embodied by the WTO. Moreover, the WTO argued that the ban was not applied uniformly on all shrimp exporters. The WTO argued that the United States did not fully exhaust the potential for fostering an international agreement on turtle conservation methods. The emerging view at the WTO is that international agreements rather than unilateral import bans or tariffs are the preferred method of addressing international environmental issues. To date, no international environmental agreements have been invalidated by the WTO.

In addition, following the Mexican tuna decision, the WTO has taken the position that trade restrictions (bans, tariffs, etc.) cannot be imposed on a product purely because of the way it has been produced. Thus, seemingly in conflict with the nondiscrimination doctrine of the WTO, domestic firms whose production methods are regulated to protect the environment, labor, and human health are placed at a disadvantage over foreign importers. Moreover, one country cannot use trade restrictions to reach out beyond its own territory to impose its standards on another country. Therefore, in the absence of an international environmental treaty, U.S. markets are forced to be open to foreign products that damage the environment in ways that domestic firms cannot. Taken together, it is clear that the WTO position has restricted the tools available for assuring environmental protection, and this places downward pressure on domestic environmental regulations.

In 1996, it was proposed that the WTO be given the power to eliminate or greatly restrict ecolabeling programs that provide consumers with information on energy efficiency and environmentally friendly production techniques employed in manufacturing. These market-oriented environmental programs provide information to consumers and allow consumers to use their "dollar votes" in the marketplace to reward environmentally friendly products. The WTO position on ecolabeling is that it cannot discriminate between different importers (most favored nation) or between an importer and a domestic firm (domestic treatment). As of 2000, the WTO had not come to a decision regarding ecolabels that describe how products are made. As we have learned in the previous paragraph, the WTO does not allow trade restrictions based on how products are made. Because a key role of ecolabels is to indicate the extent to which the good was manufactured in an environmentally friendly manner, there is doubt that ecolabels will be compatible with the WTO.

Finally, expanded international trade has put great pressure on certain endangered wildlife populations. The desire for the special properties of rhino horn, bear gallbladders, or fur coats has pushed some species up to (and over) the brink of extinction. International agreements that ban such trade have reduced the volume of trade, but they have also driven what remains into the black market.

To summarize, then, the argument against international trade from a sustainability perspective includes the following:

- When capital is highly mobile, this mobility strengthens firms' bargaining positions when negotiating with unions, local governments, and environmental agencies, while it erodes livable wages, undermines the fiscal base for local government, and puts downward pressure on environmental regulations.
- Free international trade between rich and poor countries facilitates a pattern of trade in which rich countries export their trash, toxic waste, and the production of goods that generate especially high levels of pollution. While some argue that this pattern is simply a reflection of differences in the marginal utility of money and a manifestation of comparative advantage, others view this as unethical and a potential source of environmental injustice. By separating the consumption of goods from the pollution associated with these goods, the incentive to reduce this pollution is itself diluted. Moreover, if property rights and democratic systems are not in place in the low-income country, then free trade will hasten the destruction of the environment.
- The WTO has taken a series of positions that limit the tools that are available for protecting the environment, and which place domestic firms in countries with high standards at a disadvantage over firms in countries with lower standards, promoting a race to the bottom.

Although important questions exist regarding the extent to which nations should engage in international trade, the nature of the goods that should be traded, and the extent to which trade agreements should allow for trade restrictions based on production methods, it is neither practical nor desirable to eliminate trade completely. Trade has occurred between diverse human societies for thousands of years, fostering mutual understanding, the diffusion of ideas, and interdependence.

Population and Population Growth

Concerns regarding overpopulation and resource scarcity have been articulated at least as far back as ancient Babylon and Rome. These concerns may have been justified; there are indications that civilizations have collapsed because resource degradation led to desertification and climate change in northern Mesopotamia, the Aegean, Egypt, Palestine, and the Indus (Weiss et al. 1993). It is estimated that about 50 million people lived on Earth in 1000 B.C. Today's population is more than 100 times larger, and each year population rises by nearly twice the total number of humans who were alive in 1000 B.C. As Cohen (1995) reports, global population growth rates never exceeded 0.5 percent annually until approximately 1750, and never exceeded a 1 percent annual rate until about 1930. Since 1950, they have never fallen below their present level of roughly 1.33 percent per year.

How does population growth affect the health of natural resource systems? The answer depends on the scarcity and substitutability of natural resources, and on effective governance. Consider the following scenario offered by Daly and Cobb (1989):

- When human populations are very light and vital resources (e.g., food, water, building materials) are abundant, the very abundance of these resources will imply that they have a low *value in exchange*, meaning that they will not command a very high price if someone were to sell them. Thus, it is difficult for someone to amass personal wealth and income from the sale of these resources. Yet these resources have a high *value in use* and so are a type of public wealth. Hence, in this situation we have low incomes and yet a wealth of natural resources, a condition sometimes referred to as "Lauderdale's paradox" (after the work of James Lauderdale, a classical economist).
- When populations are dense and vital natural resources are very scarce, the high degree of scarcity implies that these resources will have a very high value in exchange. People will vie for private ownership of the resources in question. The high exchange value encourages the development of markets where people who own one type of scarce resource can trade them with people who own a different type of scarce resource, leading to markets and private wealth. The high exchange value of the resource will also create an incentive for people to develop alternatives or more resource-efficient technologies. In this situation, some earn high incomes, yet the stock of public wealth is relatively lower.

As Daly and Cobb (1989) argue, "[i]n the Garden of Eden private riches would be zero but public wealth would be very great. As the Garden gets crowded and previously free goods become scarce, we witness an increase in riches and perversely celebrate, while not noticing the decline in public wealth" (p. 148).

Causes and Predicted Implications of Rapid Population Growth

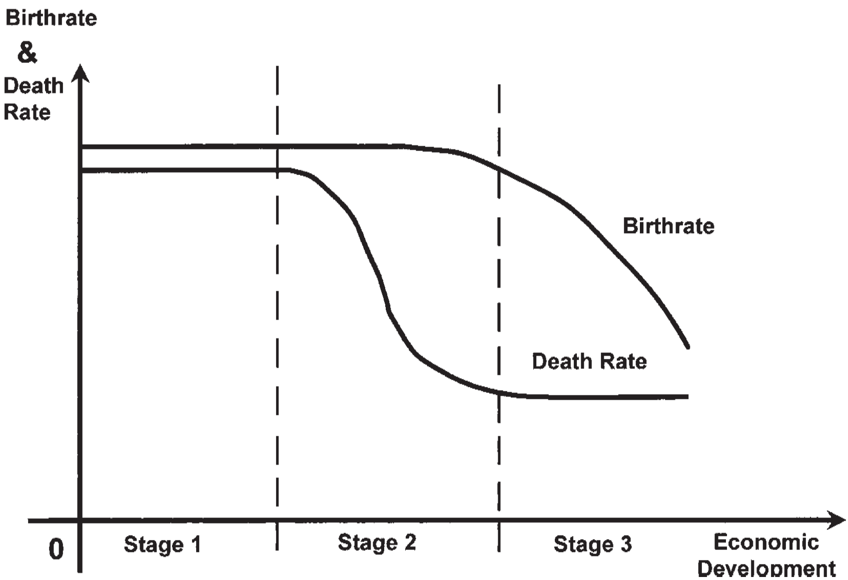
Causes. Ever since the work of Frank Notestein (1945), demographers have recognized an empirical regularity in the data on the relationship between the stages of industrial economic development and population growth rates. The evidence supports what is known as the *theory of demographic transition*, which underlies the argument used by many economists that economic growth is the key to overcoming the rapid population growth rates that we observe in many developing countries. This theory suggests that industrializing countries go through three distinct stages of population growth:

- *Stage 1:* Prior to the industrialization process, both birthrates and death rates are high, with only modest population growth. In these agrarian societies, children provide a valuable source of labor and are a form of social security in countries that lack adequate retirement programs.
- *Stage 2:* At the start of industrialization, death rates fall (largely from improvements in medical technology that reduce child mortality rates) while birthrates remain stable or fall only slightly (perhaps because technology changes faster than culture and social institutions). The result is accelerated population growth rates. Tietenberg (1996) states that stage 2 lasted about 50 years in Western Europe.
- *Stage 3:* This is the stage in which people start raising substantially fewer children, so that birthrates fall faster than the continuing decline in the death rate. Thus, in stage 3, population growth rates decline and in some cases (Western Europe is a prominent example) have fallen to zero or are even negative. Brown et al. (1984) point out that population stabilization in this process is the result of individual preferences rather than coercion and reflects a convergence of economic, social, and demographic forces. Important among the social forces are social security programs for the elderly and employment opportunities for women.

These three stages of the demographic transition are illustrated in Figure 12.2.

The argument made by many economists and demographers today is that many of the world's developing countries are in stage 2 of the demographic transition. From this perspective, the sooner they move into stage 3 the sooner world population growth will stabilize. The implication is that industrial economic development is the indicated palliative for high rates of population growth. When men and women can earn good incomes by working outside the home, when children do not bear primary responsibility for the income security of their elderly parents, and when children are schooled rather than working the farm or earning income, then the opportunity cost of having lots of children to care for becomes quite high, which works to reduce the number of offspring that people have. Erlich et al. (1995) argue that the evidence regarding this simple relationship between per capita income growth and declines in fertility is mixed; Mexico and Brazil, for example, have undergone periods of income growth with little or no reduction in birthrates. They go on to argue that fertility declines may be even more strongly related to the empowerment of women, access to maternity health programs and family-planning programs, and tax policies that encourage small families.

Figure 12.2 **Demographic Transition**



Forecasts and Predicted Effects. Thomas Malthus, the eighteenth-century economist, argued that human population growth rates exceeded the rate of growth in agricultural production. The implication is that humans can look forward to a future of famine and the collapse of society. So far, the evidence has not supported the Malthusian prediction. Two reasons present themselves. First, Malthus did not anticipate the demographic transition relating population growth rates to the stages of the industrialization process. Second, Malthus apparently did not anticipate the rate of technological advance. For example, what has been known as the "green revolution" in the 1970s was a period of rapid improvements in crop yields and methods of industrial agriculture. Although a growing number of agricultural scientists question the sustainability of the methods that grew out of the green revolution (pardon the pun), they are an example of the technological change that has so far allowed the human world to dodge the bullet of Malthusian decline despite enormous growth in human population.

While the predictions of Malthus and his followers have so far failed to manifest themselves, population growth has very clearly led to environmental harms. Deep ecologists (see chapter 2), for example, question the ethics of burgeoning human populations displacing a rapidly growing list of species and more generally appropriating what has been estimated to be approximately 40 percent of terrestrial biomass. Population growth contributes to the exhaustion of common-pool resource (CPR) systems. Examples include the decline of common grazing lands, deforestation in areas where too many people are trying to harvest wood for fuel, declines in desirable species of fish in marine and freshwater fisheries, and excessive pumping from groundwater CPRs. The interdependence of agrarian and demographic transitions leads to congestion and squalor in the cities of many developing countries. As Pearce and Warford (1993) argue, the extent of overcrowding can be gauged in part by comparing population densities per square kilometer across industrialized and developing countries. While U.S. cities such as Chicago (2,500) and Philadelphia (3,000) have relatively low population densities, cities such as Buenos Aires (15,000), Cairo (24,000), Lima (29,000), Mexico City (43,000), and Calcutta (88,000) in the developing countries have profound human congestion.

Concerns that populations in developing nations will become unmanageably large while these countries struggle to grow out of stage 2 have led to more coercive fertility-control programs and proposals. The best-known of these has been conducted by China, a country with over 1 billion people. China has a policy of penalizing families that have more than one child but has also made contraceptives readily available and has worked to provide social and economic security to the elderly, who traditionally rely on their children for support. During the 1980s, the birthrate in China declined from 34 per thousand to approximately 20. A number of economists have proposed a transferable quota scheme in which each family is endowed with the right to a certain number of children, perhaps two, but families wishing to have more than two children can purchase a "birth allowance" from those who have chosen to have fewer than two children. This system explicitly recognizes that the right to reproduce is not a free good in a crowded human world (Boulding 1964; Daly 1973; Daly and Cobb 1989). Such coercive fertility control programs are highly controversial, however, and anything less than a chronic famine is unlikely to spur their use in democratic societies, most of which have experienced dramatic declines in fertility without such measures.

What will the global human population grow to in the future? According to the United Nations Population Division, world population is currently growing at the rate of 1.33 percent annually, and it reached the 6 billion mark in 1999. From 1804, when the world passed the 1 billion mark, it took 123 years to reach 2 billion people in 1927, 33 years to attain 3 billion in 1960, 14 years to reach 4 billion in 1974, 13 years to attain 5 billion in 1987, and 12 years to reach 6 billion in 1999. The 1992 report of the United Nations *World Population Prospects* predicted that if worldwide average fertility falls to 2.5 children per woman in the twenty-first century, there would be 12.5

billion people on Earth in 2050. To see how sensitive these predictions are to forecasts of average fertility rates, note that if average fertility rates decline to 1.7 children per woman, the 1992 report of forecasted world population would peak in 2050 at 7.8 billion. As of 1998, the global average fertility level stood at 2.7 births per woman. In contrast, in the early l950s, the average number was 5 births per woman. Fertility rates have declined in all regions of the world. For example, during the last 25 years, the number of children per couple has fallen from 6.6 to 5.l in Africa, from 5.1 to 2.6 in Asia, and from 5.0 to 2.7 in Latin America and the Caribbean. In 1998, the United Nations Population Division issued revised estimates and projections for the world's population.

The 1998 revision states that world population by the middle of the twenty-first century is expected to be in the range of 7.3 to 10.7 billion. The medium-fertility projection, which is usually considered to be "most likely," indicates that world population will reach 8.9 billion in 2050. An increasing number of countries now have total fertility rates below the 2.1 average necessary for replacement. According to the 1998 Revision of the official United Nations population estimates and projections, the total fertility rate is estimated to be, in 1995–2000, at or below the level of 2.1 children per woman in 61 countries or areas of the world. This represents 10 more countries than were in the group in 1990–1995. The combined population of those 61countries (2.6 billion in 1998) amounts to 44 percent of the global population. In the period between 1995 and 2000, the United States had a total fertility rate of approximately 2, with the most recent figure (1998) being 2.06, indicating that fertility is slightly below replacement, and therefore that immigration will be a major source of future population growth in the United States. The total fertility rate for the country is considerably higher than the 1.5 average for the industrialized world as a whole, and the reasons for higher U.S. fertility rates have not been fully established.

In comparing the 1992 and the 1998 population estimates, we can see that in just six years the estimated future population forecast changed by billions. The 1998 revision is lower than the 1992 report in part because of the devastating effects of AIDS in Africa. Undoubtedly, there will be other unanticipated impacts that will affect population. As Cohen (1995) points out, even elaborate system dynamics models have failed to predict population accurately ten or more years into the future. Predictions regarding upper limits on supportable human populations vary from the view that there is no limit to the view that the current population has exceeded Earth's carrying capacity. For example, from Kates et al. (1988) and Millman et al. (1991), we find that the 1989 primary food supply could feed up to 5.9 billion people. Millman and colleagues recognized, however, that further population growth will create price and other economic incentives for increasing the quantity of food supplied.

An alternative to the Malthusian view is offered by Boserup (1965). The Boserup hypothesis regarding population density and agricultural productivity states that increased population density, together with a greater reliance on market systems of allocation, will lead to improvements in the management of the land resource. There is evidence that Boserup effects result in an increase in the utilization of organic fertilizer and integrated crop–livestock systems that enhance soil fertility, and the Boserup hypothesis has been supported by a number of studies (Ruthenberg 1980; Pingali et al. 1987; Tiffen et al. 1994). Heath and Binswanger (1996) argue that the evidence from Kenya, Ethiopia, and Colombia suggests, however, that the factors given in the Boserup hypothesis are not sufficient, and that sustainable agricultural systems are more dependent upon social and economic policies that present farmers and others with the proper incentives. For example, some developing nations have instituted policies that promote large-scale, export-oriented cattle ranches over small, labor-intensive farms, pointing to the importance of factors other than population density and market capitalism.

Taxes and Incentives

Taxes have been around since the early civilizations in Babylon, India, Rome, Greece, China, and pre-Columbian Central and South America. As Webber and Wildavsky (1986) report, early taxes were placed on food production and labor in the form of tithing and conscription. With the advent of more developed civil societies such as in Rome, taxes were placed on wealth and traded commodities. Thus, for millennia human civilizations have taxed productive activities to raise funds for government services and operations. Roodman (1996) reports that in contemporary rich countries such as the United States, Japan, and Germany, tax revenues primarily come from (1) profit and income taxes (roughly 30 to 40 percent of the total); (2) employment and wage taxes (roughly 30 to 40 percent); (3) sales, import/export, and value-added taxes (roughly 15 to 25 percent); and (4) property taxes (roughly 2 to 10 percent). Lower-income countries receive a larger share of their tax revenues from sales, import/export, and value-added taxes. Global taxes total approximately $7.5 trillion, or about one-third of the value of measured global economic output, and so they are a major factor in the world's economies.

Taxes distort the incentives naturally produced by the market system. In addition to being the basis for public finance, taxes also have the effect of raising the cost of the taxed activity and thus to a greater or lesser degree creating a disincentive to engage in the taxed activity, which you may recall is one of the principles of pollution taxation discussed in chapter 9. Thus, higher employment taxes dilute the incentive to create jobs; higher income taxes dilute the incentive to work hard or invest in costly specialized education; higher sales taxes mean that some low-income people will go without; higher property taxes reduce the affordability of homes for low-income people.

At the same time that societies use taxes to discourage productive activities, they encourage destructive activities such as resource depletion and environmental degradation through a variety of different subsidies. For example, Roodman (1998) reports that the external and hidden costs created by automobiles in the United States—such as pollution-induced environmental and health impairment, automobile injuries, and the costs hidden in the military budget allocated to energy security—amount to an estimated $300 billion to $350 billion per year, or $2.40 to $2.80 per gallon of gasoline. Contrast these external and hidden costs to the typical pump price in 1996 of about $1.20 in the United States. The $2.40 to $2.80 per gallon of gasoline amounts to an implicit subsidy to drivers who buy gasoline, paid for by taxpayers and those who bear the environmental, health, and safety costs.

Another example of a subsidy for environmental degradation is offered by the 1872 Mining Act, which requires the U.S. government to sell mineral rights at a small fraction of their market value, and requires taxpayers to pay an estimated $32 million to $72 million in abandoned-mine cleanup costs. According to the *World Development Report 1992*, in that year, there were $230 billion in fossil-fuel subsidies around the world, with about 85 percent of the total in the former Soviet Union, China, and Poland in the form of subsidized state-run energy monopolies. Eastern European transition economies on average were subsidizing electricity at a rate of more than 55 percent, while China and India subsidize electricity at a rate of more than 40 percent, and the average subsidy in other developing countries is approximately 35 percent. The World Bank (1995) estimated that removal of these subsidies would reduce carbon dioxide emissions in China, India, and other developing countries by just under 6 percent. Subsidized fossil-fuel energy prices in these countries led to wasteful energy use and large-scale pollution such as acid rain. In contrast to the developing world, Japan and other rich Pacific countries impose on average a 200 percent tax on fossil fuels, while the average figure for rich European countries was about 170 percent, and that for the United States and Canada is roughly 30 percent.

The basic argument of ecological tax reform is to shift the source of tax revenues from productive to destructive activities, thus more fruitfully employing the incentive effects of taxation. As Roodman (1998) observes, pollution taxes are the most direct way for governments to enforce the "polluter-pays" principle. By removing harmful subsidies and raising taxes on pollution and resource depletion, and reducing taxes on neutral or beneficial things such as wage income, society receives many dividends. Ecological tax reform creates a disincentive to pollute, improves the economic basis for cleaner energy forms, and increases after-tax income for working people while maintaining revenue neutrality. Taxes on resource depletion, such as for oil, gas, and coal, allow society to share in the Hotelling rents associated with their increasing scarcity (see chapter 5 for a description of Hotelling rents). Some of the first experiments with ecological tax reform have occurred in northern Europe. In 1991, Sweden reduced total income taxes by $1.65 billion and shifted the source of tax revenue to sulfur dioxide ($3,050 per ton), carbon dioxide ($120 per ton), and other pollutants. Roodman reports that one year later, Sweden's sulfur dioxide emissions had fallen by 16 percent. Denmark has shifted approximately 3 percent of the tax burden from income to a range of pollutants and resource-depleting activities. The Worldwatch Institute (2000) reports that as of early 2000, eight countries—all in Western Europe—had raised taxes on environmentally harmful activities and used the revenue to pay for cuts in taxes on income.

The barriers to implementation of ecological tax reform include adjustment costs for people and industry, though perhaps the largest impediment is political pressure exerted by those industries and consumers whose tax burden would increase as a consequence of the change. Gradual change and a well-informed and empowered citizenry are likely to be key elements of successful transition.

Thinking Long Term: Discounting and Policy-Making

Sustainability makes explicit a long-term time horizon. A central challenge is in bringing future impacts into present policy-making. As we saw in chapters 5 and 6, discounting is required for dynamic efficiency. One of the questions addressed below is whether discounting is consistent with sustainability. If discounting can indeed be made consistent with sustainability, then the next question that arises is whether the discount rates associated with competitive financial markets are consistent with those required for sustainability. Because financial markets are central to contemporary market capitalism, this discussion of discounting brings us to the larger question of whether market capitalism is consonant with sustainability.

Individuals discount future benefits and costs for a variety of reasons that are similar to why we must pay interest when we borrow money. When a lender allows you to use its money today, the lender is forgoing using that money now so that you can use it. What could the lender have done with that money besides lend it to you? Two possible options include

- consumption spending today and
- investment of that money in an income-generating activity.

Thus, the opportunity cost of lending you money is either the forgone benefits of current consumption, or the forgone income that could have been earned by investing the money in an income-generating asset, whichever is most preferred by the lender. In commercial money markets, the interest rate on borrowed money must be larger than the lender's opportunity cost in order to generate a supply of loanable funds.

Recall that if we know that an environmental policy today will generate a benefit equal to \$*B* that will occur exactly *T* years from the present, and if policymakers use a discount rate equal to *r* (assume for simplicity that it is constant over time), then the *PDV* of that future benefit today is given by:

$$PDV = \$B/(1 + r)^{T}.$$

The hypothetical example below illustrates how discounting affects the dynamic efficiency of environmentally friendly investments.

The Effect of Discount Rates on Environmentally Friendly Investments and Sustainability: An Illustrative Example

Suppose that Samantha has just bought an older, uninsulated house. Samantha commissions an energy audit and finds that an adequate insulation job would cost approximately \$3,000. Samantha's career usually requires her to move every five years or so, and realtors have told her not to count on recovering the cost of the insulation job in the resale price. Thus, Samantha has a five-year time horizon and is considering paying an up-front (time-zero) expenditure of \$3,000, which will in turn generate energy cost savings over the five-year horizon. Based on the energy audit and estimated energy prices, Table 12.1 indicates the costs associated with the options of insulating or not insulating.

Samantha wants to select the dynamically efficient option based on cost savings. Let us compute PDV for a variety of different discount rates:

$$PDV = -\$3{,}000/(1 + r)^0 + \$800/(1 + r)^1 + \$800/(1 + r)^2 + \$840/(1 + r)^3 + \$880/(1 + r)^4 + \$880/(1 + r)^5.$$

We can compare net cost savings from insulation based on a number of different discount rates, as shown in Table 12.2. Note that Samantha's dynamically efficient choice depends on the discount rate that she uses. As the rate at which Samantha discounts a future payment over current payment increases, the financial advantages of home insulation decline. Somewhere

Table 12.1

Hypothetical Example: Cost Savings from Home Insulation

	Year						
Option	0	1	2	3	4	5	Total
Insulation added	3,000	1,000	1,000	1,050	1,100	1,100	8,250
No insulation added	0	1,800	1,800	1,890	1,980	1,980	9,450
Cost savings from insulation	–3,000	800	800	840	880	880	1,200

Table 12.2

Hypothetical Example: Cost Savings from Home Insulation for Different Discount Rates

	Year						
Discount rate	0	1	2	3	4	5	Total
0 Percent (0.0)	–3,000	800	800	840	880	880	1,200
5 Percent (0.05)	–3,000	761.91	725.62	725.64	723.89	689.49	626.64
10 Percent (0.1)	–3,000	727.27	661.16	631.10	601.50	546.82	167.85
15 Percent (0.15)	–3,000	695.65	604.92	552.32	503.14	437.51	–206.47

between the 10 and the 15 percent discount rate, Samantha finds that the home insulation project fails to pay for itself. This example illustrates how discounting affects the dynamic efficiency of environmentally friendly investments. In addition, two related issues are raised by this illustrative example. The first has to do with determining whether we can characterize a discount rate that is consistent with sustainability, and the second has to do with relating this sustainable discount rate (if it exists) to the discount rates generated in financial markets. These issues will be addressed below.

The Opportunity Cost of Capital and the Social Rate of Time Preference

The Opportunity Cost of Capital

As was alluded to above, the opportunity cost of lending money in financial markets is primarily generated by the income that can be earned by investing the money in some other income-generating asset. In economics, the term *capital* traditionally refers to the tools, equipment, factories, inventories, offices, and other human-made instrumentalities that generate income through their employment as factors of production. A profit-maximizing firm that is considering investment in capital (e.g., to expand a factory or to add new equipment to a production process) evaluates this investment by comparing the anticipated flow of income generated by the particular capital investment under consideration to the various other investment opportunities open to the firm. In other words, each dollar invested in capital generates income known as the *rate of return*, and a profit-maximizing firm seeks the highest rate of return on each dollar of invested capital.

Of course investment returns are not guaranteed; it is possible that invested capital will be lost if markets change or if firms fail. Thus, riskier investments tend to offer a *risk premium* in the form of a higher rate of return on invested capital. The *opportunity cost of capital* to a firm is the next best (risk-adjusted) rate of return that was forgone when a particular investment decision was made. When someone buys a share of stock, he or she owns a portion of a publicly traded firm and so owns a right to the net income generated by the firm. This investor can sell this share of stock if a better (risk-adjusted) rate of return can be found in some other form of investment, such as the interest generated on a U.S. Treasury Bond. Hence, the opportunity cost of capital generally refers to the prevailing risk-adjusted rates of return available in financial markets. A typical benchmark is a 10 percent rate of return, which is approximately the average rate of return on publicly traded shares of stock in the United States in recent history.

The Social Rate of Time Preference

While the opportunity cost of capital forms the basis for discounting by optimizing entities in financial markets, the *social rate of time preference* forms the basis for discounting in policies designed to broadly enhance the well-being of society over time. The social rate of time preference has two elements—the rate at which a society's wealth-generating capital stocks grow and the pure rate of time preference. Let us first consider *growth discounting.* Consider a society with a stable population and no inflation that is committed to a sustainability standard and which accepts some degree of substitutability between the various forms of capital (as defined in chapter 11). Suppose a proposal is made to invest money in enhancing future natural capital by reducing emissions below the level at which they accumulate and thus pollute the air, water, or soil in the future. Suppose further that natural increases in productivity (e.g., from technological innovation) result in a 2 percent per capita annual growth rate for human and human-made capital. Then diverting a dollar of investment in human or human-made capital today means that we forgo a 2 percent social rate of return. Given the assumption that we can substitute human and human-made capital for natural capital, then the opportunity cost of social investment in natural capital is a 2 percent real rate of return on human or human-made capital. If various forms of capital are perfect substitutes, then the future benefits of an up-front investment in natural capital should be discounted at a 2 percent annual rate to make it comparable to the natural growth rate in the productivity of human and human-made capital.

Even if we only allow for one type of capital, if that capital stock is growing relative to population, then people in the future will have greater income than people in the present. It is generally accepted that the marginal utility of income (broadly defined as the flow of benefits deriving from various forms of capital) declines as income grows. If a society has steady-state population and growing capital stocks, then its income is growing over time. Yet if income is higher in the future, then the marginal utility deriving from this income is becoming smaller (and so total utility is growing at a slower rate than income). Based on this argument, consumption of a given unit of income next year will generate a smaller level of utility than if consumption of the income had occurred today. This difference in utility can also be seen as the basis for growth discounting—in an increasingly wealthy society, future income is discounted because it will generate greater utility today than next year. Note that if population growth is occurring faster than capital stocks, then it is possible to have *negative growth discounting.*

Let us now consider the *pure rate of time preference*, which is based on factors such as impatience—people would rather consume now than in the future—and fundamental uncertainty regarding whether a person will be alive to consume in some future period. The pure rate of time preference forms the basis for consumers in markets applying positive discount rates in their consumption and savings decisions. If the correct growth discount rate is zero or negative, then the only basis for a positive social rate of time preference is the pure rate of time preference. Yet, while it makes sense for individuals to have a positive pure rate of time preference, given the probability that an individual will die before future consumption can occur, this probability is clearly much higher than that which applies to the survival of humans as a species. By the same token, it is not clear that impatience is a good reason to include a positive pure rate of time preference when constructing a discount rate for sustainability policy purposes. As Azar and Sterner (1996) argue, the choice of pure rate of time preference is a question of value judgments, and at the societal level there is no good ethical argument for using a pure rate of time preference other than zero.

Thus, it can be argued that sustainability policies can be made dynamically efficient through the use of the social rate of time preference, and the soundest element of the social rate of time preference is growth discounting.

Yet if we relax the assumption that human and human-made capital can substitute for natural capital, then even the use of growth discounting can break down. Sustainability cannot generally be made compatible with dynamic efficiency under the low-substitutability scenario, which limits the applicability of benefit/cost analysis. Such a situation calls for alternative policy models such as the application of safe minimum standards to irreplaceable elements of natural capital such as biodiversity, wilderness habitat, and certain waste-assimilating functions of Earth's biosphere.

Are the Discount Rates Associated with Competitive Financial Markets Consistent with Those Required for Sustainability?

In contemporary financial markets in the United States, firms apply discount rates based on a risk-adjusted opportunity cost of capital that is several times higher than the social rate of time preference. This would seem to suggest that the investment decisions generated by financial markets will be biased toward projects and management plans that generate current rather than future benefits, and thus may not be consistent with sustainability. As the example below illustrates, financial markets treat natural and human-made capital as perfect substitutes when it comes to rates of return, implying that the opportunity cost of capital drives management decisions for commercial natural resources.

Recent developments with Maxxam Inc./Pacific Lumber Company illustrate the difficulties associated with publicly traded firms' managing their assets based on discount rates lower than those applied to similar assets in financial markets. The Pacific Lumber Company was founded in 1869 and owned approximately 190,000 acres of highly productive redwood forestlands in Humboldt County, California, south and east of Arcata. Albert Murphy, the grandson of the founder, at least implicitly recognized the need for sustainable forestry, and set up a harvest plan in which the company would never run out of "old-growth" trees 150 or more years old. This form of conservative forestry management is consistent with a relatively low discount rate, as old-growth trees grow very slowly and thus add little additional commercial value over time. As a consequence of these conservative forest management practices, by the mid-1980s Pacific Lumber owned approximately 70 percent of the old-growth redwood in private hands, creating a virtual monopoly on the supply of extremely durable and valuable lumber from the heart of these old trees (Harris 1995). Apparently, the discount rate implied by Pacific Lumber's management plan was substantially lower than the prevailing discount rates for similar forestland assets. This made Pacific Lumber an acquisition target, because its management plan was inconsistent with maximizing the discounted present value of profits at a higher discount rate; Pacific Lumber was "undervalued" based on its conservative management practices.

Thus, with financing arranged by Michael Milken, an expert in junk bond financing, Charles Hurwitz's Maxxam Corp. managed to acquire a controlling interest in Pacific Lumber. Management practices were changed to increase the logging cycle substantially and to cut the remaining inventory of old-growth trees, a process that ultimately led to one of the largest forest-related protests in U.S. history in September 1996. Soon after the protests, a deal was struck, and federal officials agreed to acquire 7,470 acres of the remaining old-growth groves at a cost of $380 million. The Pacific Lumber case illustrates the dilemma of "environmentally friendly" corporate management practices in the context of competitive financial markets; these firms that manage their assets based on below-market discount rates become takeover targets, creating a form of "market discipline" that undercuts more socially or environmentally sustainable practices. In this sense, our contemporary form of market capitalism may not be consistent with sustainability.

Rice et al. (1997) offer a very similar account of the economics of tropical forestry practices in Bolivia. Dollar-denominated accounts in Bolivia offer real (inflation-adjusted) annual interest rates averaging 17 percent—a decent measure of the after-inflation opportunity cost of capital. Moreover, mature mahogany trees (and mahogany prices) grow slowly, and so delaying harvest for a year increases the value of the tree by only about 4 or 5 percent, much less than the 17 percent (inflation-adjusted) opportunity cost of capital. Finally, delaying harvest places the timber company at risk of policy reversal. Thus, Rice and his colleagues find that the financially optimal strategy is for loggers to harvest mahogany trees as quickly as possible and invest the proceeds in financial markets to yield high returns; unrestricted mahogany harvest is two to five times as profitable as forestry practices designed to sustain the mahogany resource.

If it may not be feasible for publicly traded firms to select environmentally friendly management practices that imply below-market discount rates, then might this same argument also hold for policymakers? Horowitz (1996) has identified a form of *time inconsistency* associated with just such a case. While a policymaker today may want to commit future policymakers to a sustainable policy path, when that future becomes the present, new policymakers feeling the pressure to generate current returns may have an incentive to deviate from the sustainable path, and instead select policies that are dynamically efficient based on prevailing discount rates. This means that the original commitment was time-inconsistent. One way around this time inconsistency is to make a large capital investment in pollution control that cannot easily be reversed. Another is for policymakers to use a market discount rate but to assign a very high value on *future environmental amenities.* As Horowitz (1996) points out, "[a] high value of future environmental amenities, discounted at the market rate, will on paper look much the same as a low environmental discount rate. Yet this price approach avoids the inconsistency problem and, at the same time, ensures that future generations' interests are adequately represented in policy analysis" (p. 74).

Summary

- Income and economic growth may have both pro- and antisustainability properties in the contemporary human world. Growth in per capita incomes raises people out of squalor and poverty, makes cleaner technologies available, and contributes to lower population growth rates. Conversely, economic growth is associated with high levels of consumption and disproportionate emissions of greenhouse gases, ozone-depleting chemicals, trash, and toxic wastes. In a world of rich and poor, the rich can export dirty and destructive production practices to poorer countries that are more desperate for sources of income.
- The benefits of education and empowerment are much less ambiguous. There is clear evidence that education raises incomes in general, and increased social, reproductive, and economic empowerment for women results in higher family incomes, reduced child mortality, and substantially reduced birthrates.
- Like economic growth, international trade has both pro- and antisustainability properties. International trade allows for specialization along the lines suggested by comparative advantage, and creates wealth that increases material standard of living. Yet capital mobility results in a "lowest-common-denominator" effect in which communities with strong labor and environmental protections export their businesses and production facilities to those with weaker protections.
- The GATT and its successor, the WTO, have reduced the economic tools that sovereign nations have available to them to promote and maintain environmental and labor standards. The WTO does not support trade restrictions that regulate the way that imports are made, thereby placing regulated domestic producers at a disadvantage.
- Ecological tax reform is based on the notion that activities that are taxed are discouraged. While most economies tax things that are either neutral or beneficial, such as earned income and employment, it is also common to find environmentally harmful subsidies for coal and oil. Ecological tax reform proposes removing such subsidies where they

occur, raising taxes on environmentally harmful inputs and goods, and reducing taxes on neutral or beneficial elements of the economy such as wage income and employment. A growing number of European countries are implementing ecological tax reform.

- Sustainability also requires that we think long term. A challenge to effective sustainability policy is that of "market myopia," namely, that the plethora of profit opportunities in contemporary financial markets leads to discount and interest rates that are inconsistent with sustainability.
- Arguments for the root causes of environmental degradation and failures of sustainability include rural poor living in ecologically fragile environments; government failures in selecting and enforcing appropriate property rights regimes; the concentration of power and lack of accountability associated with large multinational corporations and their relations with corrupt local governments, particularly in developing countries; relatively unconstrained international trade in garbage and toxics, and trade agreements that treat legitimate environmental protection measures as trade barriers; failures of democratic process and local empowerment caused by discrimination and concentrations of political power and political access; government or corporate control of major news media that limit news critical of corporate or government practices; the short-term orientation created in part by high returns on capital in financial markets; perverse incentives created by taxing productive activities and subsidizing polluting and resource-depleting activities; and finally, the lack of leadership in fostering an ethic and a vision of sustainability.

Review Questions and Problems

1. Develop an international trade policy that allows trade yet also protects those who live in countries with relatively strict labor and environmental standards. How would your trade policy be different from that of the WTO? How would the leaders of exporting countries in the developing world feel about your policy?
2. Explain the relationship between income and the quality of environmental and natural resources in a given country. In particular, explain why one might expect an inverted-U-shaped relationship (a "Kuznets curve") between levels of per capita income and environmental degradation. Can you think of any situations in which this relationship might not always exist?
3. Explain why empowerment, education, and opportunities for women and other disadvantaged groups are positively related to a more sustainable society. Your explanation should go beyond the issue of democratic process to include impacts on economic vitality and environmental integrity.

Table 12.3

Hypothetical Example: Cost Savings from Purchasing a More Fuel-Efficient Furnace

	Year						
Option	0	1	2	3	4	5	Total
80% Efficient furnace	1,000	1,200	1,200	1,300	1,300	1,400	7,400
90% Efficient furnace	1,500	1,080	1,080	1,170	1,170	1,260	7,260
Cost savings from more efficient furnace	–500	120	120	130	130	140	140

4. The bioregionalist movement argues for most goods to be produced in the same bioregion in which they are consumed, limiting the role of trade and the scale of production. Discuss the merits of this proposal, with attention to its benefits and its costs.

5. Access the United Nations Population Division's Internet site (http://www.popin.org/) and find some examples of countries that have successfully reduced high rates of population growth. What policies or economic trends do you believe were responsible for reducing the growth trend?

6. Suppose that Clara just bought an older home. She expects that her employer will ask her to accept a new assignment and move in five years. Clara's house needs a new natural gas furnace. Clara is considering two options: an 80 percent efficient furnace and a 90 percent efficient furnace. The 90 percent efficient furnace costs $500 more than the 80 percent efficient furnace, but of course, the more efficient furnace will save Clara money over time because it is more fuel-efficient. Suppose that, after taking expected inflation into account, Clara projects the time-zero installation costs and operating costs over a five-year horizon to be as shown in Table 12.3.

a. Determine which of the two furnaces has the smaller discounted present value of (installation + operating) cost when Clara discounts the future at (1) 5 percent, (2) 10 percent, and (3) 15 percent.

b. Briefly discuss the relationship between discount rates and (1) the market viability of environmentally friendly products and (2) the likelihood of sustainability policies being implemented.

7. Use the Internet to research and describe an ecological tax reform policy or policy proposal. A good place to start is the Friends of the Earth Internet site (http://www.foe.org/envirotax/).

8. Use the Internet to research and describe the extent to which international development programs are addressing the education and empowerment of women, and the protection of the environment. A good place to start is the World Bank's *World Development Report* Internet site (http://

www.worldbank.org/wdr/index.htm) and the United Nations Development Program Internet site (http://www.undp.org/).

Internet Links

Ecological Tax Reform (http://www.foe.org/envirotax/): Friends of the Earth site with lots of useful material, including a citizen's guide and policy information.

Grameen Bank (http://www.grameen-info.org/): The Grameen Bank was started in Bangladesh in 1976 as an experiment of how a small amount of credit could affect the lives of the rural poor.

Human Development Report (http://www.undp.org/hdro/): You can supplement and update the material in this chapter by accessing the United Nations Development Program's current *Human Development Report* on the Internet.

United Nations Development Program (http://www.undp.org/): Learn more about the UN's view of sustainable development.

United Nations Population Division (http://www.popin.org/): Access information such as the revision of the world population estimates and projections.

Virtual Library on Microcredit (http://www.soc.titech.ac.jp/icm/): The Virtual Library on Microcredit is library, journal, and think tank rolled into one.

World Development Report (http://www.worldbank.org/wdr/index.htm): You can supplement and update the material in this chapter by accessing the World Bank's current *World Development Report* on the Internet.

World Resources Institute (http://www.wri.org/): A non-governmental organization (NGO) whose mission is to move human society to live in ways that protect Earth's environment for current and future generations.

World Trade Organization (http://www.wto.org/): You can read the actual text of the WTO decisions regarding trade disputes over gasoline, tuna, and shrimp discussed in the chapter.

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13

Sustainable Economic Development

Introduction

The goal of economic development is to improve the well-being of members of society. Nevertheless, the narrow focus on GDP that characterized economic development in the postwar period often failed to screen out projects and policies that harmed the environment, to address poverty and empowerment, and to sustain local communities and indigenous peoples. International development lending projects formed with corrupt host-country government leaders often left developing nations saddled with such large debt service requirements that essential investments in human capital such as domestic health and education programs had to be reduced or curtailed. These failings of traditional economic development served as the impetus for the sustainable development movement. The Brundtland Commission defined sustainable development as satisfying present needs without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development 1987). The concept of sustainable development is broad and has come to mean different things to different people. For example, Pearce et al. (1989) document over 60 definitions of sustainable development. As Jaeger (1995) points out, the conventional economic and ecological approaches need to be integrated if we are to progress in conceptualizing sustainable economic development as a necessary precursor to operational policy.

In this chapter, we will first consider the history and performance of conventional economic development and how some of the perceived failures of these conventional methods have provided the motivating force for work on more sustainable economic development concepts and strategies. We will then consider several competing theories of sustainable development and how particular indicators of sustainable development have been derived from these theories. We will conclude with several brief case studies that measure progress relative to various sustainable development standards.

Conventional Economic Development Strategies

The primary goal of conventional economic development has been to improve real per capita income, where income is measured from GDP. Increases in real per capita income have been a prized objective of development policymakers because rising incomes can lift people out of poverty and provide them with access to medicines, safe drinking water, and cleaner production technologies. Moreover, income can be relatively objectively measured, and so analysts can gauge the success of development policies and programs with objective performance data. As we shall see below, in the post–World War II period, international development assistance programs were modeled on the reconstruction of developed European countries, and focused on large project-based lending designed to increase per capita incomes. Unintended consequences of these economic development programs have led to the movement for sustainable economic development.

Conventional Economic Development Assistance Programs

International economic development policies take the form of technical assistance, financial assistance, and development loans. Development loans have frequently been facilitated by either the World Bank (WB) or the International Monetary Fund (IMF) pooling funds from donor countries such as Germany, Japan, and the United States and then lending these funds out to developing countries. In the 1970s, however, it was large commercial banks in the United States and elsewhere that made many of the development loans. In past decades, these loans tended to be focused on large-scale infrastructure projects such as the building of hydroelectric and other power plants, mines, irrigation networks, road systems, and port facilities.

Unfortunately, many of these debt-financed projects were economically, socially, and environmentally inappropriate. For example, loans have been used to fund large-scale resettlement of urban poor in rain forests in Brazil and Indonesia, with the result being displacement of indigenous people and massive deforestation. Loans have been used to fund large coal-fired power plants and open-pit coal mines in India, leading to massive sulfur dioxide and heavy metals pollution problems and the uncompensated displacement of thousands of local people. Loans have been used to fund massive dam projects in Thailand, displacing numerous small, locally self-governed irrigation common-pool resource (CPR) systems in which local people sustainably managed the community forests that served as watersheds for the community rice paddy irrigation systems. As Ostrom (1990) remarks, "The failure . . . to develop an effective set of rules for organizing their irrigation system is not unusual for large-scale, donor-funded irrigation systems in Third World settings" (p. 166). Thus, as Rich (1994) and others have pointed out, the record of large-scale international project lending has been one featuring substantial environmental and local community destruction and dislocation.

Both the WB and related lending programs have also failed from a financial perspective, as revealed by the WB's own Wapenhans Report in 1992 (Wapenhans et al. 1992). The report found that the WB's $140 billion loan portfolio's performance was deteriorating at an alarming rate, as measured by appraised rate of return on investment and on compliance with loan conditions. The rate of financially "unsatisfactory" projects increased from 15 percent in 1981 to 30.5 percent in 1989 to 37.5 percent in 1991. The report also found that WB staff used project appraisals as marketing devices to advocate loan approval rather than as unbiased assessments of project viability. The report also found that developing countries that borrowed from the WB saw the negotiation stage of a project as being a largely coercive exercise in imposing the WB philosophy on the borrower. Confidential surveys of WB staff indicated that substantial pressure was being exerted on staffers to meet lending targets, and that this pressure overwhelmed all other considerations; the report stated that only 17 percent of the staff in the survey believed that their project analysis was compatible with achieving project quality.

Other problems included a lack of democratic political institutions, which led to leaders who opportunistically appropriated development funds or project revenues for their own use, and an ignorance of local environmental, political, and social systems. Those projects that were successful in producing export commodities contributed to rapid growth in world commodity supplies that outpaced demand, resulting in a downward trajectory in commodity prices and repayment capability, as described below. Thus, the overall performance of large-scale international economic development lending was poor, and led to a crisis in which developing countries were faced with staggering external debt and inadequate income for repayment.

Because about one-half of the development loans were held by large commercial banks, there was fear of a collapse of the international financial system. The WB and the IMF responded to this debt crisis by offering debtor countries an opportunity to restructure their debt through *structural adjust-*

ment loan (SAL) programs. Accepting an SAL also implied that the debtor country accepted *structural adjustment plans* (SAPs) crafted by the WB or the IMF. The SAPs instituted fundamental change in a debtor country's political and economic institutions and included market-oriented reforms such as privatization of government-owned industrial enterprises, reduction of import/export tariffs and restrictions on foreign direct investment, and reorganization of economic activity. Economic reorganization was focused on promotion of export-oriented production designed to generate income from trade with rich countries.

The emphasis on export-oriented industry occurred in part because the exchange value of many debtor nations' currencies was in decline, and so exportation of goods to rich countries generated a source of *foreign exchange*, meaning acquiring the currency of countries such as the United States, Japan, and Germany whose value was far more stable. This foreign exchange could then be used to repay old external development loans. The decline in the value of debtor nations' currencies occurred for a number of reasons. One reason is that wages and sales transactions in many low-income countries are "underground" and hence difficult to tax, creating a challenge to financing government. As a substitute for taxation, governments could secretly print money and make purchases before merchants and others learned that there was more currency chasing the same number of goods and services, and thus prior knowledge of money printing led to higher prices. Eventually, people catch on to this scheme, and the result is accelerated inflation. Another reason for declining currency values is that low-income countries imported many of the finished goods and services they consumed and had little other than raw commodities to export, leading to trade deficits and currency devaluations.

The rise of external development debt and the export-oriented policies mandated by structural adjustment programs were common across many low-income countries around the world and led to a substantial increase in raw commodity exports to high-income countries. According to the WB's *Commodity Trade and Price Trends* report in 1986, natural resource–based export earnings in the early 1980s were 59 percent or more of the overall economy in countries such as Central African Republic, Ethiopia, Indonesia, Nepal, Costa Rica, Mexico, and Paraguay. The increased supply of raw commodity exports resulted in a substantial decline in the price of these commodities, as would be suggested by simple supply-and-demand analysis. This is revealed in the *barter terms of trade*, or the ratio of export prices to import prices for low-income countries. According to the *World Development Report, 1991*, the barter terms of trade for low-income countries declined by 50 percent during the period between 1965 and 1988.The decline in the value of commodity exports relative to finished goods imports reduced the income that developing nations gained from commodity exports.

In the case of Africa, for example, where a majority of export earnings came from basic commodities such as cocoa, coffee, palm oil, and minerals, Godfrey and Rose (1985) observed that "prices [fell] so rapidly with increased production and supply that increases in export volume actually result in a decrease in earnings" (p. 178). If these countries had substantial amounts of human or human-made capital, they could shift away from reliance on commodity exports, but expensive educational and capital investment schemes are beyond the reach of the very poorest of countries trying to cope with rapidly growing populations, urbanization, and hunger. To maintain adequate incomes to support both the national economy and SAL repayment schemes, more raw commodities would have to be harvested and exported.

The Brundtland Commission argued that the promotion of commodity exports in the manner described above has led to unsustainable overuse of the natural resource base for commodities such as forestry, beef ranching, ocean fishing, and some cash crops (World Commission on Environment and Development 1987, pp. 80–81). Thus, the hypothesis is that as the barter terms of trade for commodity-exporting countries decline, these countries must increase such exports in order to maintain steady export income. This puts pressure on environmentally sustainable forestry, pasturage, and cropping systems in these countries. There is some evidence supporting this hypothesis. For example, Malawi has had ten SALs since 1979, and the Overseas Development Institute found negative outcomes resulting from those SALs. Similarly, Ghana's SAP called for export-oriented cocoa production, which failed as an income-generating strategy following the collapse of world cocoa prices. In the Philippines, the World Resources Institute found that SALs encouraged overexploitation of natural resources, increased pollution, and urban decay. Moreover, analysis of tropical deforestation data by Bawa and Dayanandan (1997) uncovers a statistically significant and relatively large positive correlation between per capita external debt levels and annual tropical deforestation rates. In particular, Bawa and Dayanandan used World Resources Institute data for 70 tropical countries and looked at 14 socioeconomic factors thought to be related to deforestation. Their multiple regression analysis of the relative magnitude of direct effects indicates that per capita external debt is the single most important factor explaining deforestation rates in Latin America and Asia, whereas in Africa the debt measure is ranked behind population density in importance. Interestingly, per capita gross national product (GNP) was not found to be a significant factor in explaining deforestation.

One somewhat successful example of structural adjustment is offered by the case of Costa Rica, which was given an SAL following earlier development loan defaults. The Costa Rican economy had been primarily driven by coffee exports, and in 1982, Costa Rica experienced a crisis caused by the collapse of world coffee prices. The SALs offered by the IMF and the Inter-American Development Bank, together with $2.7 billion in U.S. aid, resulted in substantial economic and social progress. Per capita income is $5,800, 93 percent of the population has access to safe drinking water, the rate of adult literacy is 94 percent, infant mortality rates have declined from 110 to 12 per thousand births, and fertility rates have declined from 7 to 3 births per woman. Moreover, Costa Rica has diversified its exports, and in 1995 nontraditional exports generated $1.4 billion in income and represented 57 percent of total exports. At the same time, Costa Rica has managed to preserve large tracts of rainforest.

While it is arguable whether SALs strictly worsen environmental degradation in the low-income countries, the SAL program can be attacked on humanitarian grounds. As of 1995, there were 32 countries classified as severely indebted low-income countries (SILICs) (mostly in sub-Saharan Africa), having annual debt repayment obligations that are at least 80 percent of the annual GNP. Obviously, repayment requires substantial cutbacks in other government programs, particularly health and education. For example, the *World Development Report, 1992* indicated that interest payments on external debt in Latin America consume up to 40 percent of these countries' national export earnings, leaving little funds available for necessary imports, let alone healthcare, low-income assistance, job-creation programs, education, or the promotion of more pollution-efficient technologies. Oxfam International estimates that Uganda spends $17 per person on debt repayment annually but only $3 on healthcare. The UN Commission on Africa reports that expenditures on health in IMF/WB-programmed countries in Africa declined by 50 percent while these countries were under SAL programs in the 1980s, and education expenditures declined by 25 percent. To create income for repayment, SAL programs require reduced spending on imports, and one way that is accomplished is by allowing inflation-adjusted wage floors to decline, an explicit IMF/WB policy. As a consequence, income inequality and poverty have increased, even in countries such as Mexico and Chile, which are considered SAL successes.

While SALs have been damaging to most countries operating under them, they have generated substantial benefits to the donor banks and countries. Not only did the SALs force loan repayments, but by increasing the supply of commodity exports, they also contributed to lower prices for key commodities such as cocoa and coffee that are disproportionately consumed in rich countries.

Envisioning Sustainable Development: Brundtland Commission Report and the Earth Summit

A growing perception that conventional methods of economic development were failing contributed to an international movement to promote more sustainable methods of economic development. The Brundtland Commission is where the term *sustainable development* first began receiving widespread attention as an alternative to the widely publicized failures of traditional large-project international lending programs.

These sustainability concepts were further discussed and refined in a June 1992 United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro, Brazil. This meeting, more commonly known as the "Earth Summit," produced an international charter known as *Agenda 21*, a program of action for sustainable development worldwide. The Earth Summit also produced the Rio Declaration on Environment and Development, also known as the Earth Charter. From the perspective of this chapter, one of the most important products of the Earth Charter is the list of guiding principles for sustainable development.

The sustainable development principles contained in the Earth Charter represent an integration of conventional income-enhancement policies with a broad array of social, political, and environmental/ecological policies. These principles include international cooperation to help countries enhance their carrying capacity; policies to promote a more informed and empowered citizenry; a recognition of the needs of future generations; environmental laws that compensate pollution victims, limit the relocation of polluting activities or substances from rich to poor communities, and cause firms to internalize pollution costs; international agreements by which rich countries would assist poor countries in accessing clean production technologies; empowerment of local and indigenous communities to manage the resources upon which they rely; providing people with information and a voice in decision making; and the promotion of peace. Thus, from the perspective of the Earth Charter, sustainable development policies differ from conventional economic development by acknowledging the interdependencies among economy, environment, and community, and thus more completely addressing the well-being of people.

Many different policies have been experimented with that are broadly consistent with the sustainable development principles articulated in the Earth Charter. Examples include policies to increase literacy rates; the provision of microloans, entrepreneurial skills, and marketing assistance to low-income people; the imposition of pollution taxes and liability on polluters, as well as information reporting such as the Toxics Release Inventory; the fostering of appropriate legal, political, and property rights reforms needed to protect local communities that have sustainably governed their local common-pool resources (CPRs); the promotion of local small businesses to produce goods to replace imports that drain income from the community; family-planning programs; social and political reforms that empower women; the promotion of ecotourism, which generates income and employment from protection of nature preserves and biodiversity, and transforms poachers into guides and guards; and finally, direct monetary assistance and technology transfers from rich countries to promote environmentally friendlier production in low-income countries.

Sustainable development programs occur at the international, national, regional, and local level. As we learned in chapter 12, these programs are interdependent. We will return to the discussion of sustainable development policies in chapter 15, when we approach them from the perspective of the local community.

Competing Theories of Sustainable Development

There are two broad approaches to the concept of sustainable development, one that optimizes over ecological integrity as constrained by the economy, and one that optimizes over the economy as constrained by environmental and ecological considerations. Economists and ecologists argue about whether it is appropriate to discount future benefits and costs, and to substitute human-made capital for diminished natural resources, as well as about Earth's carrying capacity for humans.

As Turner and Pearce (1993) point out, following the Brundtland Commission report, there was an evolution of the ecological/economic debate into two competing theories of sustainable development, which we will refer to here as *weak-form* and *strong-form* sustainability (Pearce and Atkinson 1993; Pearce, Hamilton, and Atkinson 1996). Both forms are consistent with satisfying present needs without compromising the ability of future generations to meet their own needs. They differ in how this sustainable development mandate is achieved.

Weak-Form Sustainability

The *weak-form sustainability* theory has developed from economic models of growth and technological change in the context of limited resources. A central element of weak-form sustainability theory is the assumption that human-made capital can effectively substitute for natural capital and the services provided by ecological systems. The weak-form sustainability concept has developed from earlier work by Solow (1974) and his colleagues in understanding the conditions required for continued economic growth in a world with limited natural resources. Solow (1992) argued that a sustainable path for the national economy is one that allows every future generation the opportunity to be as well off as its predecessors. Likewise, Repetto (1986) argued that “the core of the idea of sustainability, then, is the concept that current decisions should not impair the prospects for maintaining or improving future living standards” (pp. 15–16). The concern was that if natural resources are limited, and there is little substitution between different types of natural and human-made resources, then per capita consumption may not be sustainable in a world with a growing population. Dasgupta and Heal (1979) found that if unlimited substitution of human-made capital for natural capital is possible, then exhaustible natural resources do not pose a limit to population and economic growth, even in the absence of technological advance. Hartwick (1977) developed a savings/investment perspective that helps link economic growth theory with the concept of weak sustainability. Under the Hartwick rule, in order to sustain constant levels of per capita consumption, the gains that society enjoys today from utilizing an exhaustible natural resource must be reinvested in natural or human-made capital over time. Following the benefit/cost rule, such a substitution of human-made capital for exhausted natural capital is justified as long as the increase in the productive capacity of human-made capital more than offsets the loss in productive capacity from natural capital. As Pearce (1994) alludes, a Hartwick-style savings rule underlies the Pearce–Atkinson concept of weak-form sustainability.

An implication of weak-form sustainability is that it allows for the mitigation of lost natural capital. For example, land conversion that eliminates an acre of wetland can be mitigated through the use of a number of acres of constructed wetlands. Likewise, according to weak-form sustainability, the loss of natural runs of salmon can be mitigated through the development of fish hatcheries or aquaculture.

Strong-Form Sustainability

Running down the natural environment and replacing it with technological substitutes is not widely seen as being consistent with sustainable development, however. As Victor (1991) has argued, “The easier it is to substitute manufactured capital for depleting resources or a degraded environment, the less concern there need to be about the capacity of the environment to sustain development” (p. 194). *Strong-form sustainability* theory has developed from ecological science and emphasizes the ecological imperatives of carrying capacity, biodiversity, and biotic resilience. From this perspective, human capital cannot effectively substitute for the vital services provided by ecological systems. Arguments supporting strong-form sustainability theory include (following Pearce et al. 1990):

- *Uncertainty:* The consequences of running down natural capital, and of how complex ecosystems function, are unpredictable, which suggests caution. We cannot perfectly forecast the implications of current actions in terms of how they might damage natural capital, and so we cannot determine the proper level of offsetting investment in human-made capital that is required by weak-form sustainability.
- *Irreversibility:* So many of our actions, such as species extinctions and global warming, cannot be undone. Unlike human-made capital, which can be rebuilt, destruction of certain forms of natural capital, such as biodiversity, is irreversible. Although it is possible that we can compensate future generations for permanently diminished natural capital, we are not adequately informed of the relative prices they will assign to natural and human-made capital, and so we have no way of satisfying the weak-form sustainability standard.
- *Scale:* Instead of the smooth and continuous cause-and-effect relationships assumed in the weak-form sustainability theory, we may instead have discontinuities and threshold effects. For example, ocean temperatures may rise with modest impact up to a threshold temperature beyond which rain patterns shift from continental landmass areas to open ocean, leading to drought, crop failures, and famine. Similarly, with uneven topography, each additional 1-foot rise in sea level will generally imply highly uneven land inundation rates. As a final example, loss of one species may have a small ecosystem impact, while loss of another may cause the same ecosystem to collapse.

To summarize, strong-form sustainability theory is distinguished by the view that there is very little substitutability between human-made capital and natural capital in terms of the flow of services that they are capable of providing. From a more technical perspective, another distinction is that weak-form sustainability theory is built on economic conceptions of smooth and continuous cause-and-effect relationships, while strong-form sustainability theory is premised upon an ecological systems approach that features discontinuities, discreteness, and thresholds in cause-and-effect relationships. Thus, in strong-form sustainability, the ecological systems approach provides the basis for evaluating sustainable development, whereas in weak-form sustainability, the economic methods of analysis provide the context for evaluating sustainable development. Where weak-form sustainability calls for the maintenance of the *sum* of human, human-made, and natural capital, strong-form sustainability calls for maintaining human, human-made, and natural capital separately (Costanza and Daly 1992).

There has been relatively little research that has attempted to evaluate the hypothesis of substitutability between human-made and natural capital on a comprehensive basis. Presumably, substitutability is possible in some cases and not possible in others, which would imply that the choice of weak- or strong-form sustainability is situational and complex. Pearce (1994) points out that the waste-transforming capacity of the natural environment and the degree of biodiversity, for example, have no real substitutes (though the productivity of natural sink functions has been improved by technology, as illustrated by innovative new methods of using wetlands to transform various human wastes). Empirical evidence supporting high degrees of substitutability has largely been limited to the study of energy and mineral resources (see, for example, Brown and Field 1979).

Practical Policy Implications

Policies consistent with weak-form sustainability theory are those that view natural capital, human capital, and human-made capital as substitutes. Degradation of natural capital is acceptable if, and only if, it is accompanied by a mitigating increase in human and human-made capital. This view is reflected in various World Bank positions, as expressed in the *World Development Report*, *1992* and by Pearce and Warford (1993). Therefore, for example, it may be consistent with weak-form sustainability to build a hydroelectric dam that destroys elements of natural capital if the constructed capital that constitutes the dam generates an offsetting flow of benefits.

In contrast, policies consistent with strong-form sustainability theory call for the application of a *safe minimum standard* that ensures the continued existence and minimal functional integrity of various renewable resource stocks and ecosystems from which flow food, fiber, energy, and ecosystem services essential for a sustainable society. Consistent with the notion of minimal substitutability between natural and human or human-made capital, economic growth premised on development of human and human-made capital would be constrained when pollution and other waste by-products persist in the environment and significantly degrade natural capital. As Opschoor (1996) argues, strong-form sustainability requires preserving unique and vital natural capital stocks ("ecological infrastructure") and thus keeping human activity consistent with Earth's carrying capacity and the available environmental utilization space.

Methods for Measuring Sustainable Development

We will begin by discussing measures of weak-form sustainability and then address measures of strong-form sustainability. Weak-form sustainability measures frequently are constructed by adjusting traditional measures of macroeconomic performance using various environmental and social variables. Thus, before we consider how these measures are constructed, we should briefly consider the conventional means by which macroeconomic performance is measured.

Macroeconomics is the subdiscipline of economics that analyzes the aggregate performance of an economy, with particular attention given to the *business cycle* of expansion and contraction that leads to changes in inflation, unemployment, and income. The data that are used to measure macroeconomic performance are organized into *national income and product accounts*, which were first developed by Simon Kuznets and other macroeconomists for the U.S. Department of Commerce in the Great Depression. Before that time, policymakers lacked timely and reliable macroeconomic data, and therefore were unable to take appropriate policy actions in response to current trends in the economy. Kuznets received a Nobel Prize in economics for his work with the national income and product accounts.

A central element of national income accounting is *gross domestic product* (GDP), which measures the market value of all the goods and services bought by consumers, firms, or government agencies, those invested in to enhance production by firms and other enterprises, and those involved in net exports (export minus import expenditures) each year in a particular domestic economy. When people refer to the status of the economy, they usually mean GDP. The GDP can grow over time owing to a general increase in prices (inflation) or to an increase in the productive capacity of labor and capital in the economy, or a combination of both. When one removes the component of GDP increase that is due to inflation, one is left with *real* GDP growth, or GDP growth attributable only to increases in the quantity and quality of goods and services produced. Growth in real GDP is called *economic growth*. Finally, real GDP divided by population is per capita real GDP, or the average person's share of real GDP in the economy. To central government policymakers, the key macroeconomic policy goal is to promote the highest growth rate for real per capita GDP that is consistent with a low inflation.

Consider the problem of adjusting GDP to take into account unmeasured (or incorrectly measured) changes in the quality of the social and natural environment. Many important qualities associated with a healthy natural environment or the safety and quality of our community, for that matter, are not bought or sold, and so they are more difficult to quantify and have been ignored in conventional macroeconomic analysis. Macroeconomics simply tallies up the value of market transactions, and yet macroeconomic performance defines the issues that policymakers work to address. As degradation of sensitive environmental and natural resource systems accelerates, it becomes increasingly important to find a way to adjust GDP and our system of national income accounts so that they provide a more accurate picture of the well-being of people over time—macroeconomic sustainability.

Limitations of conventional GDP accounting include the following:

- Money spent deterring and remediating crime, and other problems associated with the deterioration of communities, is counted as economic gain and increases GDP, as is money spent after a natural disaster.
- Money spent remediating pollution problems is added to the income generated by the industrial process that originally created the pollution problem, thus creating the illusion that the industrial activity creates a double benefit to society.
- GDP is not affected by the degree of inequality in the distribution of income in a national economy, and per capita real GDP does not indicate the extent of inequality in an economy. Thus, poverty can increase when real per capita GDP increases.
- GDP does not take into account moral, spiritual, or aesthetic values associated with biodiversity, wilderness, Native American religious sites, or unique aspects of the natural environment.
- GDP does not distinguish a dollar generated by sustainable harvest of a resource from a dollar generated in the process of exhausting a natural resource. From a business perspective, we can say that depreciation of the productive capacity of the *natural capital stock* is not taken into account in GDP.

Thus, simple GDP accounting treats every transaction as positive, as long as money changes hands, and therefore, real per capita GDP is inadequate as an indicator of progress toward a sustainable society. Let us now look beyond GDP to find indicators of weak- and strong-form sustainability.

Indicators of Weak-Form Sustainability

Recall that weak-form sustainability theory calls for the maintenance of a constant (per capita) level of capital stock, largely independent of whether it is human-made, social, human, or natural. Various measures have been developed that augment the national income and product accounts to arrive at sustainable income. Under idealized conditions, the national income and product accounts would include all stocks of capital and other dynamic features that affect production. Moreover, markets would accurately capture the full social value of all inputs in the sense described in chapter 4. Under these conditions, *net national product* (the sum of aggregate consumption spending and net capital formation) is equivalent to the maximum sustainable amount of consumption spending that an economy with zero population growth can indefinitely maintain (National Research Council 1999). *Net capital formation* refers to capital investment in excess of depreciation (or deterioration). Consumption spending and net capital formation would include both traditional market-based consumption and investment, as well as nonmarket consumption and investment not currently captured in the national income and product accounts. Nonmarket consumption would include the flows from resource stocks such as forests, rangelands, fisheries, and aquifers, as well as flows of ecosystem services such as oxygen exchange, temperature regulation, the hydrological cycle, and waste absorption. Accordingly, net capital formation would include investments in natural capital.

Presumably, one would also have to include consumption of the flow of services from social capital in this measure, as well as net investment in social capital. From the perspective of the National Research Council (1999), however, there is no satisfactory metric for measuring social capital, and no established methodology for valuing them in monetary terms. Therefore, social capital has traditionally been omitted by economists from augmented GDP. Recall that social capital consists of factors such as trust, norms of reciprocity, volunteerism, and networks of support. Quantitative social capital indicators include trust in government, voter participation rates, memberships in civic organizations, and hours spent volunteering. Despite the concerns of the National Research Council, some attempts have been made at valuing volunteerism and other aspects of social capital, but before addressing them, we will first consider several relatively simple indicators of weak-form sustainability.

One method of GDP augmentation that applies some of these concepts uses the Hartwick rule to derive a measure of environmentally adjusted or *green GDP*. Green GDP is derived as follows:

Green GDP = GDP – Hotelling rent for nonrenewables – total expenditures on pollution control – other direct costs due to environmental degradation.

Recall that Hotelling rent reflects the excess of (price – marginal cost) from resource extraction, and also the opportunity cost of current resource consumption. Scarce resources consumed today are not available in the future, and so Hotelling rent reflects forgone future consumption value. Hartwick and other growth theorists have shown that steady-state consumption can be maintained if Hotelling rent from consumption of nonrenewable resources is reinvested in some form of capital stock (natural, social, human, or constructed) to provide for future consumption. Thus, as nonrenewable resources are exhausted, the Hotelling rents generated by dynamically efficient consumption of these resources create a revenue source that can be invested to develop substitutes for the time when the resource is exhausted.

A closely related indicator for weak-form sustainability, developed by Hamilton (1994), is *genuine savings* (see also Pearce et al. 1996). The idea behind genuine savings is to determine whether total human-made, natural, and other capital stocks are growing, remaining constant, or declining. As the flow of benefits from human, human-made, and natural capital stocks in a given year is determined by the size of these capital stocks, measuring human-made and natural capital allows us to determine whether we are on a weak-form sustainable development path. For example, the natural capital stock represented by the number of fish in a fishery determines the amount of fish that can be sustainably harvested in a given year. Genuine savings can be expressed algebraically as follows:

$$\text{Genuine savings} = I - r(R - g) - p(e - d).$$

Note that I stands for aggregate investment in human and human-made capital of various kinds. The term $(R - g)$ is a measure of the extent to which renewable natural resource stocks (natural capital) have diminished from harvest rates R exceeding regeneration rates g. The term r is the per unit value of natural capital. Consequently, $r\ (R - g)$ is the amount that society must set aside each year as savings to offset reductions in the productive capacity of natural capital (or conversely, the added amount that society can spend if $[R-g]$ is positive). For example, these savings could be used to invest in rehabilitation of natural capital, or for further investment in substitutes such as human or human-made capital. The term $(e - d)$ reflects the excess of emissions of human wastes relative to the assimilative capacity of the environment. Pollution occurs when $(e - d) > 0$, and the term p refers to the marginal social cost per unit of pollution. Thus, $p(e - d)$ is the amount that society must set aside each year as savings to mitigate pollution-induced impairments in natural capital. In the present context where there are positive levels of pollution deposition $[(e - d) > 0]$ and resource stocks are being depleted $[r(R - g) > 0]$, genuine savings are less than investment I in human and human-made capital. The implication is that we must make further investments to maintain a constant sum of human, human-made, and natural capital.

There are a number of more ambitious measures of weak-form sustainability that include a wide variety of social, economic, and political indicators in addition to those for the environment. Two of the better-known of these socioeconomic measures of weak-form sustainability are the *index of sustainable economic welfare* (ISEW), developed by Daly and Cobb (1989), and the *genuine progress indicator* (GPI), developed by Cobb et al. (1995). Computation of the ISEW begins with per capita real consumption spending (a major element of GDP), followed by the introduction of various adjustments to take into account a variety of socioeconomic and environmental factors. The following are examples of the large number of adjustment factors that Daly and Cobb include in their index:

- Deduction of an estimate of the amount that society would need to set aside in a perpetual income stream to compensate future generations for the loss of services from nonrenewable energy resources such as oil and natural gas.
- Deduction for estimates of pollution and other environmental damages, including noise pollution, and what they admit to be a rather speculative estimate of damage from global warming.
- Deduction for income inequality.
- Addition of the nonmarketed value of household production.
- Addition of the value of government expenditures for education, health, roads, and highways.
- Deduction for the higher cost of urbanized living.

The GPI is very similar to the ISEW. To compute the GPI, one starts with real personal consumption spending, adjusts for income distribution, and then adds or subtracts a number of different elements that reflect ecological and social benefits or costs. Adjustment factors *added* to traditional consumption spending to arrive at the GPI include:

- The value of household work and parenting, based on the cost of hiring out these services, predicated on the work of economist Robert Eisner.
- The value of volunteer work, using Census Bureau data and taking the opportunity cost of time at $8 per hour.
- Services from durable goods net of their costs (from making do with old things).
- Services of government capital such as highways, streets, and other infrastructure, as a percentage of the total value of the stock of these assets.

Factors *subtracted* from traditional consumption spending to arrive at GPI include:

- Cost of crime
- Cost of family breakdown, based on added expenditures
- Loss of leisure time
- Cost of underemployment, at opportunity cost
- Cost of consumer durables
- Cost of commuting (a defensive expenditure)
- Cost of household pollution abatement
- Cost of automobile accidents
- Cost of water, air, and noise pollution
- Loss of wetlands
- Loss of farmlands
- Depletion of nonrenewable energy resources
- Other long-term environmental damage
- Cost of ozone depletion
- Loss of old-growth forests

As you might expect, green GDP, genuine savings, ISEW, GPI, and similar weak-form sustainability measures are controversial, particularly among economists. Many economists are uncomfortable with them because they are not as concrete and objective as traditional GDP accounting. For example, the dollar values assigned to GPI elements such as family breakdown and loss of old-growth forests are to some degree subjective and open to debate, while the conventional national income accounting methods underlying GDP are widely accepted. In its description of augmented accounts for tracking economic sustainability, the National Research Council (1999) excludes elements such as income inequality and the success and happiness of families. While both of these are included in the ISEW and the GPI, and in fact, inequality is a major factor explaining their trend, the National Research Council argued that such things are important, but not amenable to economic measurement. And finally, despite the complexity of measures such as the ISEW and the GPI, they still exclude important factors such as risk and uncertainty. Should the path to sustainability be risk free, or is society willing to accept policies or technologies that offer a good chance of a major improvement, but at the cost of a small chance of a loss in sustainability?

Although the weak-form sustainability measures are clearly controversial and somewhat subjective, it is also clear that current GDP accounting offers a highly incomplete view of economic well-being and sustainability. There is a growing recognition of the need for augmenting the traditional national income and product accounts. For example, the National Research Council (1999) observes that "augmented national income accounts would . . . be valuable as indicators of whether economic activity is sustainable. . . . It is clear that the national productivity depends on many nonmarket elements, including not only the environment, but such things as schooling, health care, and social capital in volunteer and civic organizations. It may not be possible to capture all these important facets of modern society in nation's accounts, but an attempt should surely be made" (pp. 15–16).

With time, a set of "best methods" may develop that will lend more precision and acceptance to measures of weak-form sustainability.

Indicators of Strong-Form Sustainability

Indicators consistent with strong-form sustainability theory include measures of ecological resilience such as biological diversity and yield variability in agriculture, measures of carrying capacity, and ecological impact analysis. As Pearce et al. (1996) point out, under strong-form sustainability theory, sustainable development occurs by conserving key elements of the natural capital stock that preserve ecological integrity.

Two indicators of strong-form sustainability are carrying capacity based on *net primary product* (NPP), and *ecological footprint* (EF), each of which focuses on measuring the natural capital requirements of human society. The NPP can be derived from the amount of vegetation produced annually over the land area of the country for which NPP is being calculated. Following Vitousek et al. (1986), one can then divide NPP by the average amount of vegetable matter required to support a human per year to arrive at a measure of the human carrying capacity of the land area under analysis. The EF is a more comprehensive measure of appropriated human carrying capacity, or the natural capital stock utilized by human society. The EF is approximated by the area of ecologically productive land and water per capita that is necessary to support existing human consumption and to absorb all waste (see Rees and Wackernagel 1994; Wackernagel and Rees 1997). Wackernagel and Rees (1997) divide land into categories: arable land, pasture, forest, sea space, built-up land, and fossil energy land. The latter refers to land set aside to sequester carbon dioxide created from burning fossil fuels. Wackernagel and Rees (1997) report that only about 0.25 hectares per capita of arable land exists, and that nearly all is already under cultivation.

According to analysis by Wackernagel and Rees (1997), the world has only 2 hectares per capita of productive surface area, including sea space. They then subtract 12 percent of ecological capacity for biodiversity, to arrive at their net figure of 1.7 hectares per capita of ecologically productive land. Because the world average per capita EF is 2.3 hectares, the implication is that humanity's consumption exceeds what nature can generate on a continuous basis by about 35 percent. As a result, the work of Wackernagel and Rees (1997) suggests a "sustainability gap" in which industrialized countries are drawing down natural capital stocks (or importing them from lower-income countries) rather than living on sustainable flows. The EF can be reduced by various combinations of more resource-efficient technologies, reduced population, reduced consumption, and increased ecological productivity.

According to their analysis, Wackernagel and Rees (1997) find that some countries are in an EF deficit, while others still have a surplus. Canada, for example, is estimated to have 9.6 hectares of available capacity for each Canadian resident, and has a per capita EF of 7.7 hectares, yielding a surplus per capita capacity of almost 2 hectares. Costa Rica is estimated to be fully appropriating all 2.5 hectares per capita that are available to its residents. Japan, in contrast, has only 0.9 hectares of available capacity for each Japanese resident, but has a per capita EF of 4.3 hectares, yielding a per capita deficit of 3.4 hectares. The United States has 6.7 hectares of available capacity for each U.S. resident, but has a per capita EF of 10.3 hectares, yielding a per capita deficit of 3.6 hectares. Deficits such as in the United States and Japan must either be imported or mined from the stock of natural capital. Mining the stock of natural capital reduces the flow of natural resources and ecosystem services that will be available in the future.

Case Studies in Measuring Sustainable Economic Development

Scotland

Moffatt et al. (1994) used both weak-form and strong-form sustainability measurement techniques to answer the question of whether Scotland is on a sustainable development path. Some of their key findings are summarized below.

- *Approximate environmentally adjusted national product, 1988–92:* According to this measure, which is basically a measure of green GDP, Scotland is on a sustainable development path, as this measure has risen without break, with a start-to-finish rise of approximately 30 percent.
- *Index of sustainable economic welfare, 1984–90* (Daly and Cobb 1989): According to this measure, Scotland is unlikely to be on a sustainable development path, as this measure has declined in all years except 1989, with a start-to-finish decline of over 10 percent. Moffatt et al. (1994) classify this as a marginal case.
- *Carrying capacity:* This ecological measure indicates that Scotland is very close to its human carrying capacity, and so Moffatt et al. classify this outcome as being marginal.

- *Ecological footprint (appropriated carrying capacity):* Analysis of Scotland's ecological footprint indicates that its present patterns of energy and food consumption are unsustainable.

The results from Moffatt and colleagues (1994) are quite mixed, and they do consider theirs to be only a pilot study. Nevertheless, as one might expect, the weak-form sustainability measures are to some extent more likely to indicate a sustainable development path than measures of strong-form sustainability.

United States

Daly and Cobb (1989) offer an ambitious study of the sustainability of the U.S. development path using the ISEW. Based on this analysis, Daly and Cobb find that the ISEW generally increased from 1950 (per capita ISEW value = 2,488) to 1979 (per capita ISEW = 3,776.4). Annual increases averaged 0.84 percent in the 1950s and 2.01 percent in the 1960s. Daly and Cobb argue that a major factor explaining the dramatic rise in the per capita ISEW during the 1960s was the increased equality of income that occurred during that period. There were also appreciable increases in net capital. Between 1979 and the end point of their study in 1986, per capita ISEW declined by approximately 10 percent (1986 per capita ISEW value = 3,402.8). The decline during the 1980s averaged 1.26 percent annually. This decline occurs even when one removes the more controversial elements from their index, such as assumed impacts of global warming. This decline is driven by worsening income inequality, further heavily impacted natural resources, and inadequate investment in socially beneficial forms of capital.

As mentioned above, Cobb et al. (1995) developed a genuine progress indicator (GPI) that includes a very broad range of environmental, social, political, and economic adjustment factors. Cobb and colleagues have computed GPI for the United States from 1950 to 1994. The GPI is an adjusted dollar measure of per capita income. Their methodology is similar to that of Daly and Cobb, and their findings are somewhat similar. Cobb and his colleagues find that GPI was relatively constant during the period from 1950 to 1961, ranging between 5,658 and 6,346. From 1961 to 1969, the GPI rose from a value of 5,872 to 7,400, approximately a 25 percent increase. The GPI declined, with a few small upward blips, through the 1970s and by 1980 was at 6,369, a level comparable to that of the 1950s. By 1990, the GPI declined to a value of 5,304, a 17 percent drop. The 1994 figure for GPI is 4,068, showing a 23 percent decline in four years. As with the analysis by Daly and Cobb (1989), much of this decline can be attributed to the increase in income inequality that occurred in the United States since the 1960s. For example, while GPI declined by 45 percent from 1973 to 1994, if income distribution had remained the same, GPI would have declined by only 10 percent.

Sub-Saharan Africa, Latin America, and the Caribbean

The World Bank (1995) computed *genuine savings* for a variety of different developing regions of the world. Although the World Bank acknowledged that this computation should also include investments in education (human capital) and health, its analysis did not include them. The World Bank's results indicate that sub-Saharan Africa has experienced negative genuine savings since 1977. Latin America and the Caribbean as a single region experienced periods of negative genuine savings from 1980 to 1984, and again in the period since 1989. Most developed countries experienced a genuine savings rate of between 1 and 10 percent annually.

Summary

- Sustainable development is about broadening the traditional mandate of economic development policies, which focus on increasing real per capita incomes in developing countries, to include social and environmental factors. The sustainable development movement is driven in part by the perception that conventional methods of sustainable development may result in serious environmental, resource, and community degradation, as well as fostering a dependency on resource-depleting commodity exports as a means of repaying past development debt.
- While conventional economic development policies have focused on fostering income growth, sustainable economic development policies also include improved education and literacy; family planning; the provision of information and democratic empowerment; the tailoring of economic development to local conditions, environments, and cultures; the promotion of ecotourism; and the fostering of environmental regulations, among others.
- Two competing theories of sustainable development have become prominent. One of these, weak-form sustainability, derives from economic models of sustainable economic growth, and is based on the assumption that technological innovation will allow for the substitution of human-made capital for depleted natural capital. The other of these, strong-form sustainability, derives from ecological models of carrying capacity, and is based on the assumption that natural capital is usually unique and thus cannot be replaced by human-made capital.

- Traditional macroeconomic accounting techniques for measuring economic performance are inadequate for evaluating the sustainability of a national economy. A number of recent attempts have been made at adjusting GDP to take into account the environmental and community requirements and impacts related to the economy. These adjustments are very difficult because of the problem of quantifying social and environmental qualities that are not directly traded in markets.
- Indicators of weak-form sustainable development include green GDP, genuine savings, the index of sustainable economic welfare, and the genuine progress indicator. These measures begin with conventional elements of GDP and make adjustments based on the monetary value of changes in the environment, natural resource systems, and a variety of social and political factors related to sustainability. Although these measures are controversial both for the factors that are included and for the values assigned to them, conventional GDP accounting offers only a very incomplete picture of the well-being of people.
- Indicators of strong-form sustainability include carrying capacity, biodiversity, and ecological footprint. These indicators provide information on the ability of terrestrial ecosystems to support human life over time. They do not allow for improved technology or for the substitution of human-made capital for natural capital.
- Case studies indicate a substantial disparity among the trend in conventional GDP, weak-form sustainability measures, and strong-form sustainability measures. For example, while real per capita GDP has generally been rising in the United States at a slow but steady pace (with the exception of recessionary periods), both the ISEW and the GPI indicate a decline in sustainable economic welfare over the last 20 or more years.

Review Questions and Problems

1. Research the effects of traditional development lending and SALs in a country of your own choice and write a two-page essay describing your findings. Discuss the impacts of development debt on the domestic economy of the country, poverty and income distribution, food security, social spending, and the integrity of environmental and natural resources.

2. Describe the conceptual differences between strong- and weak-form sustainable development. What is the basis for disagreement over which of the two offers the better guide to sustainable development policy?

3. Make a list and describe some examples of situations in which there appears to have been a sustainable substitution of human-made capital for

natural capital. Now make another list and describe some elements of natural capital that cannot be replaced by human-made capital. How might we combine elements of strong- and weak-form sustainability theory into a unified theory of sustainable development that is consistent with the two lists you have drawn up?

4. Access the Compendium of Sustainable Development Indicators on the Internet (http://iisd1.iisd.ca/measure/compindex.asp). Select an indicator of sustainability that has not been discussed in the textbook and critically evaluate how well it measures progress toward sustainability.

Internet Links

Compendium of Sustainable Development Indicators (http://iisd1.iisd.ca/measure/compindex.asp): Provides an overview of initiatives on sustainable development indicators being carried out at the international, national, and provincial/territorial/state levels. It has been prepared by the International Institute for Sustainable Development; Environment Canada; Redefining Progress; the World Bank; and the United Nations Division for Sustainable Development.

Debt Relief for Heavily Indebted Poor Countries (http://www.worldbank.org/hipc/): Read about the World Bank's program for providing debt relief to heavily indebted poor countries.

Ecological Footprint (http://www.rprogress.org/progsum/nip/ef/ef_main.html): Information and computation procedures for estimating ecological footprint, from the group Redefining Progress.

Friends of the Earth (FOE) Sustainable Societies Program (http://www.foei.org/campaigns/SSP/indexssp.html): Learn about FoE activities, campaign plans, and access their publications relating to sustainable societies.

Genuine Progress Indicator (http://www.rprogress.org/progsum/nip/gpi/gpi_main.html): Information and updates on the GPI from the group Redefining Progress.

Greening the GDP: Is it Desirable? Is it Feasible? (http://www.rff.org/resources_archive/pdf_files/139_darmstadter.pdf): Article by Joe Darmstadter in the Spring 2000 issue of *Resources* addressing the National Research Council's study of the merits of measuring green GDP, published by the group Resources for the Future. PDF file.

Index of Sustainable Economic Welfare (http://www.foe.co.uk/campaigns/sustainable_development/progress/): Information and computational procedures for estimating the ISEW, from the group Friends of the Earth.

International Institute for Sustainable Development (http://iisd.ca/): One of the best and most comprehensive sources of information on sustainable development.

Measuring Changes in Consumption and Production Patterns (gopher://gopher.un.org:70/00/esc/cn17/1997-98/patterns/mccpp5-9.txt): 1998 article on sustainability indicators by the Division for Sustainable Development, Department of Economic and Social Affairs, United Nations.

Multinational Monitor (http://www.essential.org/monitor/monitor.html): Published monthly, the *Multinational Monitor* tracks corporate activity, especially in the Third World, focusing on the export of hazardous substances, worker health and safety, labor union issues, and the environment.

Nature's Numbers: Expanding the National Economic Accounts to Include the Environment (http://books.nap.edu/catalog/6374.html): A 1999 evaluative report by the U.S. National Research Council that can be read in its entirety on the Internet.

Social Capital for Development (http://www.worldbank.org/poverty/scapital/index.htm): This World Bank Internet site is a good resource for those studying social capital.

SD Gateway (http://sdgateway.net/): Information gathered from the Sustainable Development Communications Network, including over 1,200 documents available in SD Topics, including a calendar of events, a job bank, the Sustainability Web Ring, a roster of mailing lists (listservs) and news sites dealing with sustainable development.

United Nations Division for Sustainable Development (http://www.un.org/esa/sustdev/): Internet site for the Division for Sustainable Development, Department of Economic and Social Affairs, United Nations.

United Nations Economic Commission for Africa (http://www.un.org/Depts/eca/): Lots of good information on development in Africa, including the African Statistical Yearbook.

World Bank Environmental Initiatives (http://www.worldbank.org/en-

vironment/): Read about what the World Bank is doing to promote environmentally friendly development.

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14

Issues in Sustainable Production and Consumption

Introduction

The role of production and consumption in sustainable development was a major issue discussed during the United Nations Conference on Environment and Development (more commonly known as the Earth Summit) held in Rio de Janeiro in 1992. Two important documents emerged from the Earth Summit. One of these, the Rio Declaration on Environment and Development (more commonly known as the Earth Charter) represents a statement of 27 principles of sustainable development. Principle 8 of the Earth Charter addresses sustainable production and consumption: “To achieve sustainable development and a higher quality of life for all people, States should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies.” Agenda 21, the other document that came out of the Earth Summit, represents a 40-chapter action blueprint on specific issues relating to sustainable development. Chapter 4 of Agenda 21 is addressed to the subject of sustainable production and consumption. For example, section 4.3 of Agenda 21 states that “the major cause of the continued deterioration of the global environment is the unsustainable pattern of consumption and production, particularly in industrialized countries, which is a matter of grave concern, aggravating poverty and imbalances.” Accordingly, chapter 4 of Agenda 21 states that action is needed to meet the following broad objectives:

- to promote patterns of consumption and production that reduce environmental stress and will meet the basic needs of humanity; and

- to develop a better understanding of the role of consumption and how to bring about more sustainable consumption patterns.

Agenda 21 calls on industrialized nations to take the lead in developing sustainable production technologies and consumption policies, and to help in disseminating them among lower-income countries. These technologies and policies must be demonstrated to be resource-efficient, less polluting, affordable, feasible, and attractive. Moreover, these technologies and policies should not hinder the development efforts of lower-income countries.

Several challenges are associated with sustainable production and consumption. One challenge is that the capital costs of implementing cleaner production technologies often put these methods beyond the reach of low-income countries. Lack of social and political empowerment, fossil-energy subsidies, and pressures to export resources abroad in order to repay development loans have all reinforced problems of unsustainable production in the developing world. Another challenge in the industrialized world is the disconnect between product design and packaging on the one hand—which is driven by consumer preferences for convenience and styling—and the imperatives from sustainability to reduce waste, promote reuse, and reduce the cost of materials recycling on the other. High-income countries consume a disproportionate amount of the world's resources and are responsible for emitting a disproportionate share of the world's air pollution, toxic wastes, and trash. Market systems that are largely responsible for generating the wealth and cleaner production technologies enjoyed by high-income countries also reinforce the consumer culture and the problems associated with unsustainable consumption in the industrialized world. Our ways of production and consumption are embedded in our culture, which means that moving onto a path of more sustainable production and consumption requires a cultural change. Moreover, the value of most of our capital assets and infrastructure—homes, factories, roads and highways, layout of towns and cities, facilities for generating electric power, and modes of transport—are themselves dependent upon current ways of production and consumption.

Amory Lovins of the Rocky Mountain Institute has popularized this notion that there is a strong *path-dependence* aspect to investments in homes, factories, roads and highways, the layout of towns and cities, facilities for generating electric power, and modes of transport. Once started on a particular path, it becomes difficult to change. This commitment occurs for a number of reasons: (1) Once made, infrastructure investment (highways, water/sewer/power lines) is "sunk" into place, representing a substantial financial commitment to the existing way of doing things, and making jobs and the economy itself dependent on existing methods. (2) Private R&D investment is more likely to be directed toward the security of existing systems than toward speculative alternatives, which reduces the cost of existing systems and makes them more difficult to dislodge. (3) As a technology diffuses through the economy, it becomes possible to produce at larger and larger scale. *Scale economies* (the drop in unit costs as scale or size of operation grows) develop in the chosen technology that put alternatives at a cost disadvantage. (4) The existing system becomes a standard upon which people come to rely when they make complementary investments. For example, the primacy of automobiles and extensive road networks as the transportation standard results in suburban sprawl. Thus, it is quite difficult to graft a public transportation system onto Los Angeles, for instance, because the peripheral residential areas were constructed under the assumption that people would drive their cars on freeways to get where they need to go.

There is also a problem with the political and social feasibility of sustainable production and consumption policies and technologies that is related to the problem of path dependence. As an influence group, firms will generally oppose more sustainable production methods because they will result in higher costs and lower profits. Many consumers will also oppose more sustainable production methods because some of the higher cost will be passed on in the form of higher product prices. By the same token, current systems of consumption, especially in the United States, are based on low fossil-fuel energy prices, the consumer culture, and current practices of spatially separating consumption activity and the landfilling or incineration of waste. To be politically feasible, sustainable production technology must create profit opportunities for firms, and so create a supportive economic interest group. More sustainable products must provide approximately similar service quality as existing goods and not be too much more expensive, in order to gain consumer support. Most important to the success of more sustainable production and consumption is for people to become convinced that existing systems are destructive and that a change is warranted. Once this change begins, growth in markets for more sustainable technologies and products will allow for cost-reducing economies of scale in production, and also provide an incentive for cost-reducing research and development.

We will begin with a discussion of some technologies for more sustainable consumption and production, and then turn to policies and programs that work to promote these technologies.

Issues in Sustainable Production and Consumption Technology

Solar Energy

Daly and Cobb (1989) have argued that low-entropy matter–energy is the ultimate resource for human enterprise. Further, they state that "the feature of the industrial revolution whose implications are insufficiently appreciated is the shift to fossil-fuel energy and mineral materials. This is a shift from harvesting the surface of the earth to mining the subsurface" (p. 11).

Georgescu-Roegen (1971) referred to this transformation as a shift from dependence on energy currently coming from the sun to stored energy on Earth. Daly and Cobb point out that while solar energy is unlimited in stock, the flow that arrives on Earth is strictly limited. In contrast, fossil fuels are strictly limited in stock but are relatively unlimited in available flow. Thus, the Industrial Revolution shifted the emphasis from low-intensity but abundant solar energy to high-intensity but more scarce terrestrially based fossil fuels.

Movement to a sustainable society will likely require a shift back to a greater reliance on solar energy in our economy. As Hoagland (1995) has pointed out, every year, Earth's surface receives approximately ten times as much energy from the sun as is available in the total stock of the known reserves of natural gas, oil, coal, and uranium combined. This flow of solar energy is 15,000 times greater than current levels of energy consumption by humans. The first patent for a solar-powered motor was granted to Augustin Mouchot in 1861, but cheap and readily available fossil fuels stunted the development of solar energy technologies until a brief period in the late 1970s, following the Organization of Petroleum Exporting Countries (OPEC) oil crisis. Yet by 2025, worldwide demand for electricity is forecast to rise by 265 percent. Hoagland estimates that solar energy could provide 60 percent of this electricity, and that the various direct and indirect sun-based technologies available to deliver this energy include:

- *Biomass:* The United Nations estimated in 1992 that biomass could supply 55 percent of the world's energy needs, but the water-intensive nature of photosynthetic processes will limit the production of biomass in arid environments. Hybrid willow shrub plantations, which grow ten times as much woody biomass as regular forests, are being grown in the United States and Europe to burn as biomass fuel substitutes for coal. The cost per British thermal unit (Btu) is about the same for willow and coal, but use of willow reduces sulfur emissions significantly.
- *Wind turbines:* About 0.25 percent of the sun's energy is transformed into lower-atmosphere wind, and areas that have average winds of more than 7.5 meters per second can generate electricity from wind farms for as little as 4 cents per kilowatt-hour (kWh). In 1996, wind supplied 1 percent of California's energy consumption.
- *Solar-powered heat engines:* Stirling heat engines convert between 10 and 30 percent of sunlight into electricity. Saltwater solar ponds utilize

a Rankine-cycle engine to generate electricity and also generate distilled freshwater as a by-product.

- *Photovoltaics:* Photovoltaic efficiency is currently around 30 percent, still below the theoretical limits of the technology, and as of 1996, cost limited the use of this technology.
- *Hydrogen fuel:* Hydrogen is generated by electrochemical or biological processes driven by sunlight and, as we shall see below, offers a promising method for powering clean-emissions automobiles.
- *Methane:* Methane is generated from animal wastes and biomass.
- *Ocean waves and thermal and salinity gradients in seawater:* These are large but very diffuse sources of energy.

The editors of *Scientific American* reported in September 1995 that the cost of solar power has fallen more than 65 percent since 1985. A problem with most solar energy technologies is that they are intermittent and thus must be accompanied by energy-storage systems. Hoagland (1995) argues that solar-hydrogen technologies may be the best long-term solar energy source. This technology uses sunlight falling on an electrode to produce an electric current to split water into hydrogen and oxygen ("photoelectrolysis"). The hydrogen can then be oxidized to produce electricity, generating heat and water as waste, thus making hydrogen technology a very clean energy source. Researchers working on solar-hydrogen technology at Humboldt State University have developed vehicles that are powered by this energy source. Safe hydrogen storage is one challenge confronting these researchers, but hydrogen storage is in many ways cheaper and more effective than electric energy cells.

Industrial Ecology

While referring to something (or someone) as being "linear" is a popular disparaging remark, a central facet of industrial ecology is transforming linear production processes to ones that more closely mimic the circular processes in natural ecosystems. Hawken (1994) has used the phrase "waste equals food" to refer to the cyclicity of natural systems, where nothing, or almost nothing, that is produced by one organism as waste is not a source of food or useful material for another. Traditional production methods are linear in the sense that they produce waste materials that cannot readily be assimilated as inputs in some other productive process. The result is burgeoning toxic and garbage dumps filled with materials that neither industrial nor natural processes can assimilate. There is growing concern regarding the *sink limitations* of air, water, and ground components of the biosphere.

As Froesch (1995) has argued, overcoming these problems is part technological, involving the development of new processes and materials, and part economic and social, involving the promotion and coordination of existing technologies. One well-known example of industrial ecology is in Kalundborg, Denmark. At Kalundborg, an oil refinery, an aquaculture facility, a greenhouse, and residential homes employ waste heat from a power plant. Both a chemical company and a wallboard producer utilize the sulfur waste from the petroleum-refining process. The wallboard producer uses the sulfur waste as a substitute for gypsum. Considine (2001) argues, however, that profitable waste exchange possibilities can remain unexploited for years owing to high transaction costs from technical, regulatory, legal, and organizational constraints.

Another source of inefficiency is information asymmetries. As an example of an information asymmetry that forms a barrier to the application of industrial ecology, Considine reports that firms typically do not know the quantity and quality of waste streams of other companies, or even of other divisions within a large corporation. Engineers and managers can overcome these information asymmetries and find ways to reduce transaction costs if they have the proper incentives. As an example of the importance of incentives, Considine reports that International Business Machines (IBM) achieved substantial reductions in the concentrations of heavy metals in their water effluents from their disk plants when they included environmental performance measures in their annual performance reviews of production line engineers.

There is a growing interest in product *life cycle analysis*, which involves evaluation of the environmental and resource impacts of products and services throughout their life cycle, from resource extraction to production, marketing and distribution, use, and disposal. One interesting example of life cycle analysis was conducted by the Dutch Environment Ministry regarding the environmental friendliness of reusable porcelain coffee cups, disposable paper cups, and disposable Styrofoam cups. The life cycle analysis included extraction and processing of raw materials, production of the cups, and final disposal. The analysis took into account energy use at each stage as well as consumption of natural resources, hazardous materials byproducts, and volume of waste. The biggest problem with reusable coffee cups is the water and energy required to clean them. The report indicated that washing a porcelain cup and saucer once, in an average dishwasher, has a greater impact on water resources than either a paper cup or a Styrofoam cup. In contrast, porcelain cups have less impact on air, energy consumption, and volume of trash. If a reusable coffee cup is used twice before being washed, then it becomes energy-efficient relative to Styrofoam cups after 114 uses, and less than 100 uses to be energy-efficient relative to paper. Even fewer reuses are required for the reusable mug to be more air pollution–

efficient and landfill volume–efficient. An interesting finding of the study is that more attention needs to be given to energy requirements of dishwashers and to the environmental impacts of detergents (*The Economist*, 1 August 1992, p. 58).

Environmentally Friendly Technologies Ready to Be Deployed

Moore and Miller (1994) argue that a wide variety of technologies and practices are currently available and ready to be deployed, which will move us closer to sustainable production and consumption. These include:

- Combined-cycle turbines.
- Integrated gasification combined-cycle (IGCC) systems.
- Both circulating and pressurized fluidized-bed combustion.
- Wind machines.
- Solar thermal power generation and water heating.
- Demand-side management. One example is *negawatts* earned by utilities from increased home and business energy-efficiency practices. The utility profits when conservation reduces consumption of electricity.
- Automobile technologies such as aerodynamic design, lightweight materials, and low-resistance tires.
- Selective catalytic reduction systems.
- Advanced emissions scrubbers.

Case Studies in Sustainable Technologies

Low-Emission Vehicles

Gasoline-powered automobiles are resource-intensive and account for about one-half of the pollution in metropolitan areas. Electric cars and cars powered by fuel cells appear to offer some of the best alternatives to gasoline-powered cars. Sperling (1996) reports that even electric cars powered by conventional power plants increase the efficiency of energy conversion from fuel to motive force. Internal combustion engines use less than 25 percent of the available energy in a unit of gasoline, whereas electric cars fed by conventionally generated electricity and storage cells are typically about 30 percent efficient. Under this same scenario, Sperling has also estimated the change in pollution emissions that would occur in California, the United States, France, Germany, Japan, and the United Kingdom if we were to switch to electric cars powered by existing methods of electricity generation. While hydrocarbons, carbon monoxide, and nitrogen oxides would all nearly be eliminated in countries such as the United Kingdom, the United States, and Germany, which rely on coal-powered electricity generation, emissions of sulfur oxides would increase, worsening acid rain problems, with a similar but more muted pattern for particulates. In 1990, California adopted a rule mandating a three-stage process of introducing zero-emissions vehicles as a way of reducing urban smog and other pollutants, as much as 60 percent of which is generated by gasoline- and diesel-powered vehicles. The rule required 2 percent of all sales be zero-emission vehicles by 1998, 5 percent by 2001, and 10 percent by 2003. New York and Massachusetts followed suit. Manufacturers would pay a fine of $5,000 for each car below the target. In March 1996 and again in 1998, California backed off from this rule, eliminating the 1998 and 2001 targets and allowing for "near-zero" emission vehicles.

As of 2000, the dominant zero-emissions vehicle technology appears to be a fuel-cell system. Ballard is a leading commercial producer of fuel cells. In the Ballard system, hydrogen fuel—which can be obtained from fuels such as natural gas, methanol, or petroleum—and oxygen from the air electrochemically combine in the fuel cell to produce electricity. An even more environmentally friendly method of producing hydrogen utilizes photovoltaic cells to generate a current that is run through water to produce hydrogen from electrolysis. Heat and pure water vapor are the only by-products from the fuel cell's electrochemical reaction. According to the California Air Resources Board, auto manufacturers such as DaimlerChrysler, Ford, Toyota and General Motors have announced plans to have electric vehicles powered by fuel cells commercially available by 2004. Prototype passenger vehicles are now being tested.

As of 2000, transit buses powered by fuel cells were carrying passengers in public demonstration programs in several North American cities. In addition to the efforts at developing zero-emission vehicles, an increasing amount of attention has turned to hybrid electric vehicles that have a small gasoline or gaseous-fueled engine that runs at constant speeds to produce electricity to power the vehicle and to charge its batteries. Such a hybrid can get 80 or more miles per gallon because the constant speed generator can be made to be very fuel efficient. The hybrid also does not normally require recharging from an outboard power source. As of 2000, Toyota's Prius hybrid was among the first hybrid electric cars to be widely available within the United States.

Solar Cookers

As Nandwani (1996) reports, fuelwood and agricultural residues are the major energy source for cooking in developing countries, accounting for between 50 and 90 percent of all energy consumption. About 90 percent of the fuel used for cooking in Africa is wood, for example, and worldwide it is estimated that about one-half of Earth's 6 billion people cook their food using fuelwood or agricultural residues. Yet with existing population growth rates, fuelwood-powered cooking and heating do not appear to be sustainable. The rate of fuelwood consumption exceeds the rate of reforestation and regrowth, and this contributes to deforestation at the rate of approximately 15 million hectares per year (Nandwani 1996).

Moreover, the burning of dung and other agricultural residues results in losses of soil fertilizer. The United Nations Food and Agriculture Organization forecasts that 2.4 billion people will face acute fuelwood shortages by early in the twenty-first century. Nandwani argues that solar ovens offer a far more sustainable cooking technology. He reports that a family-sized solar oven would cost between $40 and $50. While this is a sizable investment for people in the poorest of countries who frequently live on $1 per day, the increasing scarcity of fuelwood is driving up the price that rural people must pay, with fuelwood expenditures accounting for perhaps as much as 25 percent of average household budgets in places such as rural China and Zimbabwe. Thus, as Grupp (1996) argues, the availability of microloans for families to buy solar ovens may be critical, for the fuelwood savings can be used to repay the loans.

Key limitations of solar ovens include the less than full reliability of the technology owing to the inability to store energy for cloudy days, and the longer cooking times required. Despite these limitations, Nandwani (1996) reports that about 525,000 solar ovens are in use around the world. Solar ovens are well-suited as supplemental cooking devices, and they are gaining acceptability in places such as Central America, India, Cuba, and parts of Africa.

Policies Promoting Sustainable Production and Consumption

Market forces will eventually provide very powerful incentives for cleaner and less resource-intensive methods of production and consumption as price responds to growing resource scarcity and mounting environmental degradation. The problem is that this sort of sudden and reactive change in the way people live could come too late, involve sudden transitions that are costly and painful, and lead to an irreversibly damaged environment. Interventions in the form of regulations, taxes, subsidies, and direct funding of clean technology research and development are necessary to prevent potentially even greater problems in the future caused by our inaction.

Extended Producer Responsibility (EPR)

Extended producer responsibility (EPR) is a policy tool in which producers are required to be financially or physically responsible for their products after their useful life. As Hanisch (2000) observes, EPR programs are rapidly growing in popularity among European and some Asian countries. Briefly, EPR requires that producers either take back spent products and manage them through reuse, recycling, or remanufacturing, or delegate this responsibility to a third party, a so-called *producer responsibility organization* (PRO), which is paid by the producer for spent-product management. The EPR programs are designed to integrate environmental costs throughout the product life cycle into the way that goods are produced and distributed. Traditionally, manufacturers are only responsible for immediate pollution emissions, whereas municipal governments are responsible for reuse, recycling, and disposal of wastes. Under an EPR program, however, manufacturers must bear the cost of downstream waste management and recycling. Because manufacturers must pay for reuse, recycling, or remanufacturing of the products they produce, they have an incentive to "design for the environment" by making products that use less packaging, are easy to repair or disassemble, and that use fewer hard-to-recycle blended materials. Worldwide, EPR policies have been implemented in 20 Organization for Economic Cooperation and Development (OECD) countries, and in some non-OECD countries as well, according to the United Nations Commission on Sustainable Development (UNCSD Web site). Examples of EPR policies include the following:

- Germany initiated an ambitious take-back program in 1991 with the German Packaging Ordinance. As Hanisch (2000) reports, under the German Packaging Ordinance, producers of all kinds of packaged products are required to either individually take back their packaging or join the Duales System Deutschland (DSD), an industry organization for packaging waste. The DSD charges a fee to license its green dot label to firms, and the licensing agreement allows firms to print the green dot on their packaging. Consumers can then dispose of green-dot wastes in the DSD disposal system. Moore and Miller (1994) report that by 1993, some 400 randomly surveyed German companies "had completely abandoned the use of polyvinyl packaging, plastic foams, and 117 other types of packaging" (p. 36). Between 1991 and 1998, the per capita consumption of packaging in Germany was reduced from 94.7 kg to 82 kg, a drop of 13.4 percent. As of 1999, the ordinance requires that 60 percent of plastic packaging must be recycled. In 1998, the cost per ton for waste management in Germany was $360.80.
- Sweden has committed to the creation of an "ecocycle society" in which producers are responsible for life cycle wastes associated with the goods that they make and for maximizing energy and materials efficiencies. Sweden has EPR policies applicable to tires, magazine papers, and cars,

and may extend them to electronic goods. The total weight of packaging consumed in Sweden declined by 20 percent during the period between 1991 and 1998 (Hanisch 2000).

- The Dutch have created Automobile Recycling Nederland (ARN), a group that organizes materials-recovery and recycling. The Dutch have also transformed their road tax into a vehicle ownership tax that people must pay until the car is officially recycled. This tax is designed to limit illegal dumping. Moreover, the Dutch have instituted a German-style take-back program for packaging waste, though household plastic waste is not separately collected.
- Austria passed the Waste Management Act of 1990 to give government the authority to require producers and distributors to take back wastes and worn-out products along the lines of the German system described above. In October 1993, Austrian take-back requirements were created for packaging (with a 1999 goal of 80 percent), batteries, and refrigerators, among others.

Ecolabels

Ecolabel programs are designed to promote more sustainable production and consumption by providing an environmental standard for consumer goods. Typically, ecolabel programs set environmental standards (and sometimes labor standards) that exceed those set by law, and they are administered by a government agency or a trusted auditing or certifying organization. Third-party certification (the term "third party" refers to an entity other than the buyer or the seller) has developed as the most credible method for assuring compliance with meaningful standards because many people do not trust unverifiable claims made by corporations. Firms bear the cost of third-party certification, and in return can label their product as being in compliance with the ecolabel standard. Ecolabeled goods are perceived by some consumers as being of higher quality than nonlabeled goods. Therefore, firms may find that participation in an ecolabel program increases the demand for their product and differentiates it from nonlabeled rivals.

As of 1996, some 30 ecolabel programs were operating worldwide (UNCSD Web site). One of the more prominent examples of ecolabel programs is offered by Germany's Blue Angel program, which has registered 4,000 products and is the oldest ecolabeling program. According to a study by Papastefanou (1996), the number of ecolabeled products in Germany has increased from fewer than 100 in 1979 to over 4,000 in 1994. The number of ecolabeled goods dropped to approximately 3,400 in 1995, approximately the number for 1990. Papastefanou reports that people most open to ecolabeled goods in Germany tend to be middle-aged (38–42 years), employed part-time or in the home, living in small cities rather than rural or large metro areas, moderately or highly educated, middle- or upper-class, female, and with children under age six. Other countries are experimenting with ecolabel programs, including Taiwan's Green Leaf program, which has registered 200 products, and Sweden, Norway, Iceland, and Finland's Nordic Swan program. In Sweden, the market share of ecolabeled detergents increased from 12 percent in 1992 to 80 percent in 1995. The USEPA manages a number of ecolabel programs, one example of which is the Energy Star program for energy-efficient appliances and office equipment.

The issue of ecolabel programs and the World Trade Organization (WTO) was discussed in chapter 12. To review, the WTO position on ecolabeling is that it cannot discriminate between different importers (most favored nation) or between an importer and a domestic firm (domestic treatment). As of 2000, the WTO had not come to a decision regarding whether ecolabels that certify the method of production are consistent with WTO guidelines. As the shrimp and the tuna cases described in chapter 12 indicate, the WTO usually does not allow trade restrictions based on production methods unless the restriction derives from international treaties. Because a key role of ecolabels is to indicate the extent to which the good was manufactured in an environmentally friendly manner, there is doubt that ecolabels will be compatible with the WTO.

Factors Relating to the Success of Ecolabel Programs

- Both environmental nongovernmental organizations (NGOs) and industry members play a role in the development of ecolabel standards and support the standards.
- Ecolabel certification is done by "third-party" agencies or organizations that consumers can trust, and that are subject to periodic audits.
- A substantial number of people are educated about the impacts of their consumer choices on the environment, and they perceive ecolabeled goods as being of higher quality than nonlabeled goods.
- Firms can make a profit by producing ecolabeled goods.

Three Examples of Ecolabeled Goods

- *Certified Sustainable Wood Products:* The most credible of these programs utilize "third-party" certification procedures. Third party certification involves an organization such as the Forest Stewardship Council (FSC), which establishes guidelines and standards, and accredits other organizations (such as the SmartWood program of the Rainforest Alliance) that certify professional foresters, forestlands, and lumber mills. In order for wood products originating from certified sources to carry the FSC logo, the wood products must be tracked from logging operation to log transport, milling, lumber transport, and the lumberyard in a process known as "chain of custody." Chain of custody assures consumers that the ecolabeled lumber they buy was harvested in a manner consistent with FSC standards. Certified sustainable forestry has spread throughout the world. As of 2000, there were nearly 2 million hectares of certified forest in the United States, 9 million hectares in Sweden, and almost 18 million hectares worldwide (FSC Internet site). An increasing number of large retail lumberyards have become open to the idea of selling ecolabeled lumber. For example, in response to a shareholder resolution in 1999, Home Depot agreed to phase out selling lumber harvested in an environmentally harmful manner and give preference to ecolabeled lumber. Lowe's Home Improvement Warehouse made a similar decision in 2000.

- *Certified Coffee:* A number of different organizations are certifying coffee based on environmental and social criteria. For example, the American Birding Association has linked up with the Thanksgiving Coffee Company to produce Song Bird Coffee, which is certified to come from coffee plants grown in the shade of rainforests, and which provide habitat to a large number of migratory birds. The advocacy group Global Exchange has developed a "fair trade" certification for a variety of products, including coffee. According to their Internet site, to become Fair Trade certified, an importer must meet international criteria including paying a minimum price per pound of $1.26, providing credit to farmers, and offering technical assistance such as help in transitioning to organic farming. Starbucks has recently agreed to provide financial support for shade-grown coffee projects, and to market both shade-grown and Fair Trade coffees.
- *Organic Foods:* A number of states, including California, have developed production standards for organic farm products. After ignoring many of the recommendations of the National Organic Standards Board, as of 2000, the United States Department of Agriculture had taken all of their advice and developed a set of proposed national organic standards that are broadly consistent with those of California and other states. Common elements of organic food certification exclude the use of most synthetic pesticides, herbicides, and fertilizers, as well as human sludge and irradiation. Land must have been clear of prohibited substances for at least three years. Organic meats must come from animals that have not been given hormones or antibiotics, have been fed organic feeds,

and have had access to the outdoors. As of 2000, there were approximately 10,000 U.S. farms that claimed to be organic, 6,600 of which had been approved by one of the 88 different state or private certifying entities. Sales of organic foods in the United States have increased at a rate of approximately 20 percent per year, and sales in 1999 were estimated to be $6.46 billion.

Taxes, Subsidies, and Ecological Tax Reform

Most countries tax productive activities such as work (payroll and income taxes) but implicitly subsidize destructive activities such as pollution and the exhaustion of critical natural resource systems. As was discussed in chapter 12, the notion underlying ecological tax reform is that countries should shift their taxation from productive activities such as work and income generation, and onto pollution and resource exhaustion. This scheme can be revenue-neutral, meaning that total tax revenues to government remain the same. Most important, taxing pollution and resource exhaustion raises the cost of these destructive activities, thus discouraging them. By reducing taxes on productive things, such a scheme encourages employment and income generation. Sweden and Norway have established tax-shift commissions in their ministries of finance to analyze the problems and implications of shifting to more ecological taxation, according to the UNCSD.

Case Study: The California Experience in Subsidizing Alternative Energy

An interesting case study in the role of subsidies in promoting more environmentally sustainable production methods is provided by electricity pricing in California. California began offering incentives for alternative energy in the 1970s, and these incentives were designed to reduce dependency on foreign oil supplies and to promote environmentally friendly energy supply technologies. These incentives took the form of mandates that required California electric utilities to buy power from alternative energy suppliers at prices based on projections of the price of oil rising to as much as $100 per barrel. These subsidies then become embedded in the price of electricity, leading to California's having some of the highest electricity prices in the United States, 50 percent above the national average. These subsidies also have had the intended effect of promoting alternative energy: 10.4 percent of California's energy came from alternative energy sources in 1994, up from 5 percent in 1984, and California accounts for 90 percent of alternative energy production in the United States. Major sources include wind power, geothermal, and solar energy. According to the *California Statistical Abstract*, in 1998 geothermal, biomass, wind, and solar energy together supplied 8 percent of California's energy, and hydroelectric facilities supplied 18 percent.

In a time of historically low fossil-fuel prices, many Californians have become frustrated by the high energy prices that they pay. The state legislature is in the process of deregulating the California electricity industry, with the intention of reducing electricity prices. California Assembly Bill 1890 (AB 1890), which also deregulated the electricity industry, established a new statewide renewables policy by providing $540 million collected from Southern California Edison, Pacific Gas and Electric Company, and San Diego Gas & Electric over four years beginning in 1998 to support existing, new, and emerging renewable technologies from 1998 to 2001.

According to the California Energy Commission, funds for existing technologies are distributed through a cents-per-kilowatt-hour (kWh) production incentive, with a cap of 1.5 cents per kWh. Funds for new technologies will be distributed through a production incentive based on a competitive solicitation process, with a cap of 1.5 cents per kWh, and be paid over a five-year period once a project begins generating electricity. Yet, because alternative energy sources are still more costly than electricity from burning fossil fuels, many are concerned that the alternative energy market share will decline in a deregulated setting. One concern is that deregulation will make it difficult for alternative energy producers to acquire capital financing for new production capacity, because of increased uncertainty of the economic viability of alternative energy in a highly competitive deregulated market. Nevertheless, some environmentalists and renewable energy representatives are confident that many people will voluntarily select cleaner energy even if they have to pay a small price premium to do so.

Government Research and Development Funding

Direct government-financed research and development (R&D) is another obvious area of importance. In the United States, substantial increases in alternative energy and energy efficiency R&D occurred in the years following the OPEC- and Iranian-induced oil price shocks in the 1970s. For example, the U.S. Department of Energy's R&D spending on renewables and energy efficiency was $1.4 billion in 1980. A combination of factors, including the collapse of oil prices in the early 1980s, led to a sharp decline in alternative energy R&D, with the 1993 budget being $200 million. Compare this R&D spending in 1993 to the $500 million spent on fossil-fuel R&D and over $600 million spent on nuclear energy R&D.

ISO 14000 International Environmental Certification

An important international voluntary environmental certification program is in the process of development. Since 1947, the International Standardization Organization (ISO), a worldwide federation of national standards bodies, has been providing voluntary technical, safety, and other standards for manufacturing and other production processes around the world. The ISO standards are constructed through a consensus process and are highly regarded internationally. Following the formation of the World Trade Organization (WTO) in the Uruguay Round of the General Agreement on Tariffs and Trade in 1986, which established the principle of regulatory "harmonization," a need was recognized for developing international environmental standards. The ISO 14000, currently being developed, would provide a uniform international certification for manufacturing and other firms based on their sustainable production characteristics. The ISO intends to have its 14000 certification program recognized by the WTO as providing a special technical support role in harmonizing international environmental regulations.

The management standards for ISO 14000 are being developed by six subcommittees and one working group:

- SC1: Environmental Management Systems
- SC2: Environmental Auditing and Related Environmental Investigations
- SC3: Environmental Labeling
- SC4: Product Life Cycle Assessment
- SC5: Environmental Performance Evaluation
- SC6: Terms and Definitions
- WG1: Environmental Aspects and Product Standards (Rhodes 1995).

Case Study: The Global Race for Environmentally Friendly Technology

In their study of the global race for environmentally friendly technology, Moore and Miller (1994) compare the progress of Japan, Germany, and the United States, the three most powerful economies in the world. Following the OPEC oil crisis, the United States invested substantial resources in R&D for alternative energy and energy-efficient (as well as resource-efficient) technologies. Having done much of the early basic research, the United States drastically cut its R&D funding during the 1980s, when OPEC's cartel price collapsed and the era of cheap oil resumed.

Germany's R&D efforts began picking up as the United States began to decline. During the 1980s, the shocks of Chernobyl and *Waldsterben* (widespread forest death caused by air pollution, which in 1985 was estimated to involve 50 percent of Germany's culturally important trees) galvanized concerns for the environment in Germany. As a result, Germany began instituting what have come to be some of the most stringent pollution and environmental regulations in the world, including large-scale subsidies for solar power research, public transportation, and energy-efficient manufacturing technologies. Germany's Ordinance on the Avoidance of Packaging Waste in 1991 initiated Germany's famous "take-back" program, described above.

Japan has few fossil-fuel resources, and its profound exposure to world energy markets, illustrated by the OPEC oil price shocks of the 1970s, spurred Japan to develop energy-efficient production technologies. Today, Japan uses less energy per unit of output than any other industrialized country in history, and half as much as in the United States. Myers (1992) reports that Japan, because of its effective response to the oil price shocks, uses less energy per person, and less energy per dollar of GDP, than any other rich industrialized nation.

One of Moore and Miller's central arguments is that there is a type of "first-mover advantage" in clean production and consumption technology. Those countries that develop these technologies first will have a head start in profiting from exporting them to other countries as they become confronted with the need to change. Thus, Germany's rigorous environmental regulations are promoting the development of pollution-control technologies that it can later market worldwide. Japan's sustained focus on energy efficiency has placed it in a commanding position to market these more energy-efficient technologies around the globe. The global market for "environmental goods" has been estimated to be around $200 billion per year and is expected to grow substantially in the twenty-first century. The U.S. Agency for International Development predicts the global market for energy technology to be $2.1 trillion over the next 20 years.

Moore and Miller (1994) report that U.S. leadership has declined in the production and implementation of wind turbines, solar cells, fuel cells, and cool-water (IGCC) coal-burning technologies. Germany is now the world's leader in pollution-abatement equipment, according to the OECD. Japan is the largest exporter of air pollution–control products. Profit opportunities from exportation of environmental technologies help explain why countries with strong environmental standards also have healthy economies. Moore and Miller cite an unpublished paper by Myers in which he finds that "states [countries] with stronger environmental standards tended to higher growth in their gross state products, total employment, construction employment, and labor productivity" (Moore and Miller 1994, p. 75).

Summary

- The traditional view is that sustainable production is the problem of low-income, developing countries that cannot afford cleaner production technologies and that sustainable consumption is the problem of high-income, developed countries with the money to consume a vastly disproportionate share of the world's resources. For example, it is estimated that on average, each person in the United States consumes the same amount of energy as ten people in developing countries.
- Practically speaking, however, all countries are confronted with the challenges of sustainable production and consumption. Japan, Germany, and the United States are all actively engaged in R&D for developing environmentally friendlier technologies. Though government promotion of clean technologies has declined in the United States, commitment has continued or increased in Japan and Germany.
- Sustainable production and consumption technologies can be promoted by governments through a combination of EPR programs, tax/subsidy schemes, ecolabeling systems, technology-forcing mandates such as the U.S. standards for automobile fuel efficiency, direct funding of R&D activities, and various educational programs.

Review Questions and Problems

1. Select a particular clean technology and find out where the technology was developed, where the products are produced (or if they are being produced), and where they are sold. What factors, if any, limit sales of this technology relative to traditional technologies?
2. In the absence of some sort of government policy promoting clean technology, what types of environmentally friendly technologies will the market process produce and sell, and why? In the case of recycling, why is it important that both government policies and markets be coordinated?
3. Go to your local grocery store or coffee shop and compare the price of standard and ecolabeled coffees. Is there a price premium for the ecolabeled coffees over and above what is charged for the standard coffee? Ask the manager if the ecolabeled product is perceived as being successful. You might also compare certified organic fresh produce with standard produce at your local grocery store. Write up your findings in a one-page essay.

Internet Links

Fair Trade Coffee (http://www.globalexchange.org/economy/coffee/): Learn more about the fair trade coffee campaign from the advocacy group Global Exchange.

Forest Stewardship Council (http://www.fscoax.org/): Read more about certified sustainable forestry.

Is Extended Producer Responsibility Effective? (http://pubs.acs.org/hotartcl/est/00/apr/hanis.html): Article by Carola Hanisch in the April 1, 2000, issue of *Environmental Science and Technology*.

National Organic Program (http://www.ams.usda.gov/nop/): This USDA Internet site describes the revised national organic standards.

OECD Environment Website (http://www.oecd.org/env/): Although OECD countries make up only 19 percent of the global population, they are the major consumers of the world's natural resources. Read about OECD member country initiatives, indicators, and sectoral studies related to sustainable consumption. Material is also provided on sustainable production topics such as increasing resource efficiency and sustainable transportation. Site maintained by the Organization for Economic Cooperation and Development.

Online Fuel Cell Information Center (http://www.fuelcells.org/): Learn more about fuel cells and zero-emission power sources.

Solar Cooking Archive (http://solarcooking.org/): Find out more about this environmentally friendly technology. The country reports are especially useful.

Sustainable Consumption and Trade (http://www.iied.org/scati/): Internet site provided by the International Institute for Environment and Development devoted to promoting practical ways of making international trade and global consumption serve the goals of sustainable development.

The Earth Council (http://www.ecouncil.ac.cr/): You can read the text of the Earth Charter and Agenda 21 and learn about efforts at implementing the proposals generated at the Earth Summit.

U.N. Sustainable Development Publications on Sustainable Production and Consumption (http://www.un.org/esa/sustdev/newspubs.htm): Read a number of reports and discussion papers on trends and case studies in sustainable production and consumption.

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15

Issues in the Economics of Sustainable Local Communities

Introduction

There has been growing interest in the sustainability of national economies and in promoting sustainable economic development at the macroeconomic level. But there has also been a growing recognition that the principles governing a sustainable society may be most effectively applied to smaller local communities, which is the focus of the present chapter. For one thing, it is at the local community level where the scale of decision making is most consistent with democratic process and the empowerment of people. As Ostrom (1990) has found in her research, sustainable common-pool resource (CPR) systems appear to be linked to effective local self-governance, which connects community with its natural resource life-support system. Yet local communities cannot wall themselves off from national and international trends, migrations, and trade. Sustainable local communities must not only find equitable methods of governing themselves and their local commons, but also develop strategies for relating with the forces of the larger national and international economy and with the dynamics of in- and out-migration.

Sustainable Local Self-Governance of Localized CPR Systems

For hundreds, perhaps thousands, of years, local communities have had rule systems for jointly managing and using those common lands and other resources that typically lay between deep wilderness and the farmstead, and that were not suitable for cultivation (Snyder 1990). Common lands were typically used for grazing livestock, the gathering of fuelwood and building materials, and varying degrees of hunting and gathering of wild animals and plants. The use of these lands (or fishing grounds) was governed by local tribes or village communities. Typically, these rule systems limited access to people from outside the community and related the intensity and frequency of use by those in the community to the resource's carrying capacity. For example, as we learned in chapter 5, some tribes such as the Yurok in northwestern California utilized both private property and common property systems depending on the nature of the resource in question. In a very important sense "the commons" constitutes both the resource and the community institutions of self-governance that connect that resource to the people who depend upon it. As Gary Snyder (1990) has stated, the commons is the contract a people make with their local natural system. There is, unfortunately, a long history of centralized government authorities failing to recognize locally devised traditional common property regimes. The result has often been the loss of local community rights and controls. One prominent example is the enclosure movement in England and parts of Europe, which resulted in many village commons being transformed into private estates.

As was shown in chapter 5, the salutary effects of Adam Smith's invisible hand—that self-interested behavior is transformed into the common good by way of decentralized markets—do not extend to CPR systems. The central problem is that there is rivalry in consumption of the natural resource in question. For example, when someone adds more cattle to the communal grazing land, there is a disparity between the flows of benefits and costs. The benefits flow to the person who added more cattle to the communal grazing land, and may take the form of greater income from selling more calves or dairy products. The costs, however, are shared by all who use the grazing commons and take the form of less feed and degraded range conditions. Thus, a self-interested maximizer sees an opportunity to increase his or her herd without limit, receive 100 percent of the income, and share only a fraction of the cost. This is the mechanics of what Garrett Hardin called the "tragedy of the commons," which refers to the incentive for self-interested maximizers to impose *appropriation externalities* on the community whose members together rely on the CPR system.

What is interesting from the perspective of this chapter is that there are sustainable, long-enduring local communities that have not succumbed to the tragedy of the commons. Ostrom (1990) provides some of the most comprehensive analyses of the nature of these long-enduring and sustainable local communities and their relationship to the local natural resource systems on which they depend. The enduring role of common property resources such as grazing land and forestland in these communities is perhaps surprising to resource economists, who see private property as the solution to resource degradation. What one observes instead is a lasting, parallel existence of both private and communal property in communities where people exercise control over institutions of governance and property. Drawing upon her field research, Ostrom observes, "Generations of Swiss and Japanese villagers have learned the relative benefits and costs of private property and communal-property institutions related to various types of land and uses of land. The villagers in both settings have *chosen* to retain the institution of communal property as the foundation for land use and similar important aspects of village economies. The economic survival of these villagers has been dependent on the skill with which they have used their limited resources. One cannot view communal property in these settings as the primordial remains of earlier institutions evolved in a land of plenty" (p. 61).

The tragedy of the commons is a characteristic of open-access property regimes and of other property regimes where rule systems have failed.

Examples of Sustainable Local Communities and the Systems They Use for Governing CPRs

Törbel, Switzerland

As related by Netting (1981), for centuries the people of Törbel, Switzerland, have relied on a combination of private and communal property. Privately owned plots are used to grow grains, vegetables, fruit, and hay. Five different types of common property have been acknowledged in written legal documents that date back to 1224:

- Alpine grazing meadows
- Forests
- Wastelands
- Irrigation systems
- Paths and roads connecting private and communal property

In 1483, the villagers agreed to a system of self-governance to better manage the use of communal property. A central element of this rule system limits access to the village's communal property. For example, regulations written in 1517 state that "no citizen could send more cows to the alp than he could feed during the winter" (Netting 1976, p. 139). Ostrom reports that the wintering rule is used by many other Swiss villages as a means for allocating grazing rights. Moreover, those with rights to use the village communal property are given the power to decide whether additional people should be admitted to community membership. The boundaries of the communal property are well-defined. A local official is authorized to impose fines on those who put an excessive number of cows on the communal alp and to keep half the fine. Each family receives a share of the village's cheese in proportion to the number of cows it grazes relative to the total. Villagers have voting rights and have created an alp association to hire staff, impose fines, and arrange for manure spreading and other necessary maintenance of the common property. Those who use the grazing commons provide labor in proportion to the number of cows they graze. Trees needed for fuel and construction are selected by the village and assigned by lot to households. Before the rapid rise in population in the nineteenth century, Netting (1976) reports that severe population pressure was held in check by measures such as late marriages, high celibacy rates, long birth spacing, and a great deal of emigration.

As Ostrom reports, Netting's major findings are consistent with experience in many other Swiss communities. Throughout the alpine region of Switzerland, private property exists for more intensive cropping, while common property is used for summer meadows and forests. In fact, 80 percent of the Swiss alpine area represents some form of common property. Ostrom cites an unpublished work by Hartmut Picht that reports that all local regulations limit the level of appropriation from these commons. Overuse of alpine meadows is rarely reported.

Japanese Village Commons

McKean (1986) estimates that approximately 12 million hectares of Japanese forests and mountain meadows were managed as communal property between 1600 and 1867, and that about 3 million hectares are so managed today. As in Switzerland, villagers in the Japanese villages studied by McKean use private property for valuable land that is more intensively cropped for rice and vegetables and use common property for larger areas of less valuable forestland and grazing land.

Spanish Irrigation Commons

Irrigated agriculture has been critical in Spain, where limited and highly seasonal rainfall would otherwise severely restrict agricultural productivity. Ostrom (1990) reports that Spanish towns and villages have had self-governed irrigation systems for at least 550 years, and probably for close to 1,000 years. These systems require farmers to construct and maintain canal and ditch systems and to agree on how to allocate scarce water supplies. These irrigation areas that surround or are near the villages that govern them are referred to as *huertas*.

Interestingly, farmers lost control over their irrigation systems during the Spanish Civil War and did not regain this power until 1950. Moreover, the freedom that farmers had to self-organize was peculiar to the traditional region of Aragón in eastern Spain. As Ostrom (1990) points out:

> By the time the centralized monarchy based on the Castilian model came to dominate Spain and Latin America, the autonomy of the *huertas* was well established. The continuing willingness of the irrigators in these regions to stand up for their rights attests that they had greater autonomy than did those in other parts of Spain. One can only wonder if the course of history in Latin America might have differed substantially if the Spanish monarchy established by Ferdinand and Isabella had been modeled on Aragón and not on Castile. (p. 81)

Ostrom finds that similar communities with long-standing communal irrigation systems exist in the Philippines, referred to as *zanjeras*. As with the *huerta* system, village communities have retained substantial autonomy to determine their own rule systems, including durable methods for assigning water, monitoring rule conformance, and providing labor for canal and ditch maintenance.

Localized Self-Governance of Fisheries

Schlager (1993) evaluated the varying degrees of success experienced by 30 locally self-governed coastal fishing grounds worldwide. Three problems that develop in these settings are *appropriation externalities* (tragedy of the commons), *technological externalities* (gear entanglement and other forms of physical interference from fishing boats working adjacent to one another), and *assignment problems* (boats that locate themselves inefficiently on the fishery, such as when too many are clustered in one place). Schlager points out that fishers organize themselves to coordinate their harvesting activities. She finds that this coordination has successfully reduced assignment problems and technological externalities relative to cases in which self-governance did not occur. Schlager also argues that it is extremely difficult for fishers to resolve appropriation externalities because of the problem of determining whether a decline in catch is due to overfishing of that species, overfishing of a species lower on the food chain, environmental circumstances, or even how many fish are landed by other fishers. Accordingly, Schlager finds no instance among the sample of coastal fishing grounds she studied in which fishers utilized a quota scheme. Thus, fishers try to regulate the use of the space of their fishing grounds rather than the overall catch.

Sanctions of various kinds have been found to be associated with successful local self-governance of fisheries. For example, Acheson (1988) studied Maine *lobster gangs*, which are groups of fishers who make informal (but very real) territorial claims for harvesting lobsters. Sustainable harvest rates in these territories have been achieved in part by use of sanctions such as destruction of the equipment of outsiders who repeatedly enter the territory claimed by the gang. In their study of local fishery self-governance in the Bahia region of northern Brazil, Cordell and McKean (1992) find an elaborate system of social norms and rules for ethical conduct on the CPR. These rules are devised to prevent exhaustion of the fishery and to distribute access rights equitably. Violation of these norm-based rules of conduct can result in sanctions such as ostracism and sabotage of fishing gear and equipment. Thus, mutual monitoring and sanctioning appear to have been important to sustaining local fisheries and the communities that depend upon them.

Fodder and Fuelwood Use in Panchayat Community Forests

The panchayat community forests occur in the mid-Himalayan Mountains in the Almora District of Uttar Pradesh, India. Agrawal (1993) studied six of the nearly 4,000 villages with panchayat forests. These forests are managed by local groups called *van panchayats*, councils made up of five elected people who set rules for forest use. For example, Agrawal found that most villages have allocation rules that limit the time in which villagers can harvest fodder, usually 2 to 12 weeks. When tree leaves are cut for fodder, at least two-thirds of the leaf cover must be left on the tree. While in some villages people are given equal allocations of fuel and fodder, in others the rights are proportionate to the contributions made by each person in maintenance (tree planting) and monitoring (directly, or indirectly by paying the salary of a guard). Agrawal found a very strong link between the level of village investment in monitoring and dispute resolution systems, the degree of village commitment to sanctioning violators appropriately, and the resource conditions in the panchayat forests. In the less successful villages studied by Agrawal, panchayat officials did not emphasize monitoring. Moreover, two of the three less successful villages used rule systems that discriminated against lower-caste people, and monitoring was primarily used to punish these lower-caste people.

In contrast, successful villages linked a guard’s pay to performance, and panchayat officials monitored the guards. In one of these villages, violators were required to confess in front of the entire village, creating a strong deterrent to violating the shared social norm of sustainable use. The failure of these three villages to construct adequate rule structures for governing panchayat forests explains the subsequent resource degradation in these forests.

After extensive field research, Ostrom developed a set of *design principles* that she found to be consistently associated with enduring, sustainable CPR governance systems. These principles are also supported by the later studies of Schlager and Agrawal, as described above, and by Pye-Smith and Feyerabend (1994) in their case-study analyses of successes in local community environmental management.

Ostrom's Design Principles Associated with Sustainable Local Self-Governance of Common-Pool Resources

1. *Clearly defined boundaries:* Boundaries regarding who has the right to appropriate from the commons, and regarding the CPR itself, tend to be clearly defined.
2. *Congruence between appropriation and provision rules, and local conditions:* The rules that govern withdrawal of resource units from the CPR are tailored to local conditions. *Local conditions* include culture, the biomechanics of the CPR, and differences between resource users, among others. Rules that govern the provision of human-made CPRs similarly match local conditions. This principle argues against the "one rule system fits all" approach to self-governance.
3. *Collective-choice arrangements:* All *stakeholders* (people who use or are impacted by the CPR) are included in the formation of appropriation/provision rules and in rule adaptation over time.
4. *Monitoring:* Those who actively audit CPR use and conditions are accountable to the appropriator group or may be the appropriators themselves.
5. *Graduated sanctions:* Sanctions or punishments imposed for violation of rules reflect the extent of the harm imposed and the context of the offense, and they are established by the appropriator group themselves.
6. *Conflict resolution mechanisms:* Appropriators and their officials have rapid access to low-cost arenas in which to resolve conflicts among appropriators or their appointed officials.
7. *Minimal recognition of the rights to organize:* External government authorities do not block or hinder local self-governance.
8. *Nesting of small-scale governance systems within larger governance systems when localized CPRs are part of larger systems:* Layering of governance structures matches the interdependence and complexity of CPR systems.

Both Ostrom's research and Agrawal's work support the idea that successful CPR governance must include clearly defined boundaries between the CPR and either private property or other CPR systems. Rule congruence linking appropriation with local conditions and with provision of maintenance or monitoring effort is also linked to successful self-governed systems. Principle 3 above points out that successful CPR self-governance is linked to an inclusive, democratic process, one of the key elements of a sustainable community. Principles 4 and 5 indicate the importance of deterrence to cheating on appropriation and (effort) provision rules—groups must provide for effective monitoring and must have credible sanctions that are appropriate to the extent of the transgression. Principle 6 illustrates the importance of mediation, arbitration, and other alternative dispute resolution methods to sustainable local communities. The failure of centralized governments to recognize local groups' rights to self-organize to manage their localized commons (principle 7) has been a problem for U.S. and Canadian inshore fishers and elsewhere. Finally, principle 8 provides a hint for how these very small-scale success stories can be replicated at larger scales. The idea is for larger, more complex systems to have nested within them highly localized self-governing groups. Then the larger, more complex and interdependent system can be self-governed by representatives from the various small-scale self-governing groups. Ostrom also makes the point that success in small-scale self-governance creates social capital and organizing skills that can then be used for larger and more difficult CPR problems.

Retrospective on CPRs and Local Self-Governance

Ostrom (1990) has argued that important similarities are shared by various long-enduring communities and their systems of CPR governance. The natural environments where these villages exist feature important uncertainties such as unpredictable rainfall and snowfall, and so successful rule systems are adaptable to changing natural conditions. In these situations, community members share a common understanding of the merits of continuing the status quo relative to various feasible changes in rules and norms of acceptable behavior. Importantly, populations in these villages have remained stable over long periods of time. Well-defined social norms prescribe a rather narrow band of acceptable behavior that facilitates interdependence with minimal conflict. As one would expect, the costs of being ostracized are quite high and, together with mutual monitoring of behavior, lead to powerful reputational incentives, which promote conformance to shared social norms of sustainable use. Community members tend to be very similar in terms of wealth, education, ethnicity, and race, and this homogeneity also limits conflicts. People who live in these communities share a common history and can reasonably expect to have a common future together. Because the rule systems can accommodate generational transfers of rights and land tenure, people can expect that they are making decisions that will determine the quality of life of their children and grandchildren. As Ostrom points out, this promotes very low discount rates and thus leads to policies that are consistent with community sustainability.

The case study research described above points to the central importance of social capital and the evolution of behavioral norms of restraint and cooperation that are consistent with sustainable use of CPRs. Sethi and Somanathan (1996) have developed a theory that explains why norms of behavior that restrain the use of CPRs can persist in social settings that might otherwise favor self-interested behavior. They use the mathematics of evolutionary processes and apply them to social and economic institutions such as the rules that communities use to govern CPRs. Their theoretical analysis is consistent with the extensive case study literature, namely, that social norms that restrain overuse of the CPR and provide sanctions for those who violate these norms can remain stable over time even when there is occasional intrusion by self-interested people. They also show, however, that factors such as a rise in the market price of the resource in question, or diminution of the impact of available sanctions, can produce a fatal instability in sustainable local self-governance from which it is extremely difficult to recover.

Successful local self-governance appears to be associated with only modest asymmetries in the distribution of local power and influence, a factor that is also linked to the quality of local democratic processes. For example, the villages studied by Agrawal (1993) that featured rather rigid caste structures and discriminated against lower-caste people were less successful in sustainable self-governance. Similarly, proposals for local environmental dispute resolution through collaborative, stakeholder-based self-governance, cannot be expected to succeed in local settings where certain stakeholders have disproportionate power and influence. Thus, community economic development centered around attracting disproportionately large business or government operations may undermine the quality of democratic local self-governance, and so ultimately may not be consistent with community sustainability. As we shall see in the discussion below, protecting the quality of local self-governance forms one of the arguments for community economic development strategies that instead focus on assisting local small businesses that produce for local consumption, and substitute for goods that would have to be imported into the community.

The Economics of Sustainable Community Development

This section primarily focuses on the sustainable development dilemma confronting relatively small local communities in industrialized countries that feature large and highly specialized industrial enterprises, an extensive reliance on interregional and international trade, and free migration of people from one community to another. In this context, many of the self-governance principles developed by Ostrom are difficult to implement, and the property rights to community qualities are essentially open-access. Given the inability of U.S. communities to limit access to community qualities under the constitutional freedom of interstate and intrastate migration, and the many books and magazines specializing in rating the quality of local communities for those considering a move, what strategies are available to local communities wishing to sustain meaningful work and income-generating opportunities, as well as the environmental and community qualities that make the community a desirable place to live?

Export Base versus Import Substitution

Power (1996) contrasted the strategy of attracting large export-oriented industry with the strategy of promoting diversified and smaller-scale local businesses that produce goods that replace imports for local consumption. This subsection outlines and builds on the arguments made by Power.

The Export-Base Theory of Local Economic Development

The notion of local communities competing for large, export-oriented enterprises for job and income creation is derived in part from the theory of the regional economic base (see, for example, Richardson 1969 and Sirkin 1959). The concept of the regional economic base, which is at the heart of the export-base theory, is that the level of jobs, income, and other economic activity in a local area is primarily determined by those sectors of the local economy that are sustained by demand from outside the local area. Thus, these economic-base industries inject income into the local community as a consequence of exporting locally produced goods and services to buyers outside the community.

The export focus of the regional economic base model starts out from the recognition that a wide variety of different goods and services are imported to local communities from other places. For example, few communities manufacture their own automobiles, and so cars and trucks are imported into the community. When these imported goods are sold locally, the payments naturally flow out of the community to those who originally produced them. In a community with no offsetting income flows from outside the community, the stock of savings and wealth would eventually be drained away by these payments for imported goods. Thus, for a community to sustain itself over time, it must have export-based income to offset income leakages caused by the purchase of goods and services imported into the community. The economic base refers to those primary commercial activities that are the central driving force for injecting income into the local economy by way of export sales outside the community.

Income generated by the economic base of a community then supports a web of supporting businesses that serve those who own or are employed in economic-base industry, such as grocery stores, clothing and shoe stores, health care, restaurants, and those skilled in various trades, crafts, and professional services. Thus, a dollar of income injected into the local community by export sales from the economic base is then multiplied as it flows through the supporting businesses. The size of this multiplier effect is determined by the extent to which the community imports goods and services rather than by producing its own import-substituting goods and services.

To see how the economic-base model works, consider the following simplified example: Suppose that a new lumber mill is opened in a community, and it generates $5 million in export sales. Some of this income goes to pay for inputs used to produce milled lumber that come from outside the local community, such as raw logs, energy payments, transportation services, and equipment rentals or payments. Moreover, some fraction of the net income earned by the lumberyard flows to owners who do not live in the local community. Suppose that of this $5 million, $2 million flows out of the community right away as payments for production inputs and to owners from outside the community. Thus, $3 million is initially injected into the local community in the form of payments for locally sourced inputs, such as parts and hardware, wages, salaries, profits, and locally sourced equipment rentals and payments. This injection is then spent by the people who received it as income, including workers at the mill, the owner of the hardware store, the equipment dealer, and any local owners of the mill. Some of this spending—say, 50 percent—leaks out of the community on purchases of imported goods. For example, the hardware store owner spends some of this income on inventory orders from outside the community, and workers spend some of their income on car payments to dealerships in neighboring communities. Thus, the initial $3 million injection generates an additional $1.5 million in local spending. This second round then spurs additional rounds of spending. For instance, the workers and the hardware store owner spend money at the local grocery store, and the local grocery store spends some of that income on wages and locally sourced food, and some of it on food imported from outside. Thus, the third round of spending is $750,000. Spending continues until leakages exhaust the process. Ultimately, a total of $6 million in local income is generated by the increased exports of milled lumber. The formula used in this computation is:

Total increase in income = (local injection) × multiplier.

And:

Multiplier = 1/(leakage rate).

Thus, the initial injection was $3 million from the economic base, and there was a 50 percent leakage rate. The smaller the leakage rate is (meaning the smaller the fraction of local income being spent on imports), the larger the multiplier is, and so the greater is the total volume of local income ultimately generated by an initial injection from the economic base. This formula is a simplified version of the more general case developed by Sirkin (1959) and assumes that savings by community members that leak out of the community in the form of loans (for example, money market mutual fund investments or savings in large national banks) are just offset by loan funds in the community that come from savings outside the community. This is also the simplifying assumption used by Power (1996). There are other assumptions such as the availability of excess production capacity and the relative sensitivity of imports and exports to income that go beyond the scope of the current presentation.

With this simplified view of the local economy in mind, let us now turn to the traditional strategies for economic development. A primary goal for traditional economic development has been to spur economic growth in order to reduce unemployment rates and to increase family and per capita incomes. Unfortunately, as we shall see below, past economic development policies have led many state and municipal economies to improvements in one area that are offset by declines in the other. In the long term, policies spurring local economic growth encourage in-migration and population. In countries where people are relatively free to migrate from one place to another, additional job opportunities in one community attract people from many others, either directly by word of mouth or as wages are bid up by localized labor scarcity and employers look to outside the community for workers. Opportunities outside the community will draw away some young and mobile people; more generally, international and national-level economic and political forces will play a dominant role in determining local economic conditions. These forces are beyond the control of the local community. Thus, a single-minded focus on increasing jobs will assure a long-run increase in an area's population, but cannot assure an unemployment rate that is appreciably different from that in other locations with similar quality-of-life attributes.

Consider the performance of various states and municipalities in the United States. There is evidence that rapid rates of job growth are often associated with even more rapid growth in-migration, leading to downward pressure on wages and family incomes. In particular, Power (1996) evaluated the relationship between states with very high growth rates in job creation, and average family income for the period from 1979 to 1989. Nevada, Arizona, Florida, Alaska, Washington, Utah, New Mexico, Colorado, and Texas all had rates of employment growth in excess of the U.S. national average. In all cases except Florida, average family income in these states grew at a significantly slower rate than did the national average. In contrast, Rhode Island, New York, and Washington, D.C., all had rates of employment growth far lower than the national average, and Connecticut and Massachusetts had employment growth rates at approximately the same level as the national average, yet the average family income in these states grew at rates substantially above the national average. Although there are instances in which employment growth is associated with growth in average family income, the relationship between the two is not obvious.

Power found a similar lack of a strong relationship between job growth and growth in per capita income using data for the period 1983 to 1993. Power (1996) reported that the states with the fastest rates of growth in employment in this period—Nevada, Arizona, Utah, Florida, Washington, Georgia, Idaho, New Mexico, Oregon, and Delaware—did not experience per capita income growth in excess of the national average, and half of them experienced per capita income growth at rates below the national average. In contrast, of the ten states with the slowest growth rates in employment, seven had per capita income growth rates faster than the national average. Power also provided evidence that metropolitan areas with the fastest employment growth had slower than average growth in per capita income, while the reverse was true for metropolitan areas with slower than average employment growth. These results are consistent with the notion that areas with rapid employment growth often have even higher rates of in-migration, leading to downward pressure on wages.

Thus, we see that a single-minded focus on quantitative job creation can backfire. Moreover, in their attempt to increase jobs, many local communities get locked into bidding wars in an attempt to attract large, export-oriented firms, a process sometimes called "smokestack-chasing." In order to win such a bidding war, local communities often feel compelled to offer large tax breaks and provide land and other infrastructure. In fact, Bartik (1991) reports that there is no clear indication that reducing business tax rates has resulted in increased economic growth and plant locations. These inducements reduce the money that is available for schools, road repair, parks, and law enforcement, ultimately eroding the infrastructure capital stock of the community. As a consequence, local communities that compete in this way for large, export-oriented firms often end up competing away the benefits of this economic growth. In addition, while the large new industry will increase the population of a community, economic studies indicate that communities end up spending more per person as their populations rise, thus resulting in an increase in tax burdens for local residents.

Hence, traditional economic development strategies designed to attract large, export-oriented businesses in order to generate quantitative growth in employment will in large part be frustrated by national and international economic forces, especially migration. Moreover, the inducements that local communities offer to attract these businesses, and the population growth and increase in tax burden that result from success, will likely make local residents worse off. Nearly everywhere, however, those who are actively involved with local community development strategy are confronted with great pressure to create job opportunities.

The Import-Substitution Theory of Local Economic Development

Given the inevitable loss of firms and employers over time, and the income drain from the purchase of imports, economic development policies that can foster a vibrant and dynamic local economy are important. One alternative to the export-base model that has been suggested is to focus some attention on creating jobs by promoting import-substituting business, as opposed to the costly competition for large, export-oriented "footloose" industry. By stemming income leakages, import substitution causes the existing levels of injections from exports to have a larger multiplier effect on the local community economy. As a consequence, import substitution can be just as effective a policy instrument in promoting jobs and creating additional income. A sociopolitical argument favoring import substitution is that the scale of import-substituting business enterprise is more closely matched to that of the community, reducing asymmetries in power and influence. An economic argument is that import substitution diversifies the local economy against the risk of the big export firm's declining or closing. Unfortunately, if other communities are pursuing the export-base development strategy, then under competitive conditions *economies of scale* (the drop in unit costs as the size of a given business operation grows) could lead to imports being lower in cost than those same goods produced locally. In this case, both local support for local import-substituting firms and a willingness to pay a small price premium are the manifestations of a community's social and cultural capital that can allow local small business to survive. One example is the rise of farmers' markets and community-supported agriculture. More isolated communities may find more success with the import-substitution development strategy, as relatively high shipping costs help work against the cost advantage of imports.

A practical approach to more sustainable local economic development is to provide an environment in which local people can create and sustain local small business. These businesses are more responsive to local democratic process, employ local people, and foster pride and empowerment. Some of these small businesses may substitute for imports and stem the drain of income out of the community, while others may be a part of the economic base that injects income into the community by exporting goods and services outside the community. This may involve entrepreneurial training and marketing assistance. Some communities have experimented with small-business incubators, which are facilities that provide leasable space plus office management and marketing assistance. Education and training are one example.

Moreover, we learned in chapter 12 that microlending and small-scale venture capital financing is a highly effective strategy that promotes entrepreneurism and empowerment, for many small business startups lack access to traditional bank loans. Small business is where much of the job growth has been in the United States. As Power (1996) has argued, public investment in telecommunications infrastructure helps promote decentralized production of services and allows people the flexibility to work out of their homes. More generally, sustainable local economic development involves enhancing the local stocks of natural, human, social, and human-made capital as a way of improving the flow of resources and qualities currently in the community. Protection of the local natural environment, public commons, and the arts provides a concrete way of enhancing local quality of life that also moves us toward what may be a more appropriate balance between the commercial and noncommercial aspects of life in local communities. Businesses make location decisions in large part based on these local qualities, and so an alternative to tax giveaways and erosion of community services is to enhance community services and protect local quality of life.

Case Studies: Attempts at Moving Toward Sustainable Local Community Development

A number of strategies for more sustainable economic development have been discussed in Part III of this book and are summarized in Table 15.1. The case studies that follow help illustrate how these concepts can be applied in actual community settings.

Willapa Bay

Willapa Bay is one of the cleanest estuaries in the continental United States, and is an immensely rich fishery for oysters, clams, and crabs. Yet the Willapa Bay area of southwest Washington State ranks in the bottom third of Washington's per capita income, and the four counties in this area are listed

Table 15.1

Selected Economic Instruments for More Sustainable Local Community Development

Instruments and strategies	Description
Microlending	Very small-scale lending directed at low-income people lacking collateral. To receive a loan one must usually be part of a "solidarity group" of other borrowers who provide mutual support and help assure repayment. Microlending reduces dependency, promotes empowerment and entrepreneurism, and builds social capital among members of the solidarity group.
Promotion of local small business	Smaller communities need not compete away their tax base to attract large, export-oriented industry. An alternative strategy is to promote "home-grown" small businesses, some of which will be a part of the export base that injects income into the community, while others will produce goods and services that substitute for imports from outside and thus stem leakages. Such development promotes a more stable and diversified local economy, and is more responsive to local democratic process. For example, farmers' markets and community-supported agriculture strengthen urban/rural ties and establish a connection between environmental quality and local economic vitality.
Ecotourism	Engaging local people as guides, guards, and hosts to tourists visiting adjacent ecologically important areas. Ecotourism provides a direct financial incentive for local communities to protect their natural areas and provides an economic alternative to poaching or extractive resource harvest.
Recognizing and enforcing land tenure rights and effective local systems of CPR self-governance	Securing land tenure and property rights, and recognizing effective local systems of CPR self-governance, helps avert "tragedy of the commons" outcomes and promotes a longer-term perspective to resource management.

by the state as economically distressed. Declines in salmon and the introduction of mechanized harvest methods on the area's tree farms have resulted in declines in employment. Ecotrust, an environmental group based in Portland, Oregon, became involved in the process of more ecologically sustainable economic development. One project involved cutting and marketing alder trees, an abundant tree that had formerly been considered a weed. A problem was the lack of local venture capital. Ecotrust brought in Shorebank, a community development bank out of Chicago that had specialized in providing loans in inner-city neighborhoods and small enterprises. From this project has developed ShoreTrust Trading Group, which together with the Ford Foundation, has been involved in developing business plans and finding markets for locally produced goods (Maughan 1995). Other projects include the marketing of local oysters in the Nature's Fresh Northwest chain of natural food markets. Increasing the value of the oyster fishery provides an incentive to protect the environmental integrity of the bay.

Arcata

About 275 miles from San Francisco and over 400 miles from Portland, Arcata, California, is located on one of the most remote sections of the U.S. Pacific Coast south of Alaska. Declines in the local forest products and fisheries industries have contributed to unemployment rates substantially higher than in either California or the United States. Moreover, Arcata's remoteness makes it quite costly to export products and generate income injections into the community. Yet this very remoteness can be transformed into a strength if economic development focuses on promoting local, import-substituting products and services. The Arcata Economic Development Corporation (AEDC) has played an increasingly important role in local economic development. AEDC provides three services: (1) microloans for small-business startups; (2) assistance in developing small-business plans; and (3) management of Foodworks, a microbusiness incubator that has the capacity for 13 specialty commercial food processors such as tofu and smoked fish, and provides some management and marketing assistance. A substantial number of successful local businesses have been provided assistance at critical stages of their development from AEDC. Many of these produce import-substituting food products, while others represent outdoor clothing and equipment and other specialty manufactures. In 1995, a number of food-processing and other firms formed Humboldt Harvest, a cooperative marketing organization designed to promote import substitution and create regional export markets for locally produced goods. Arcata also has a thriving farmers' market that features organic and other produce from area farmers as well as community-supported agriculture programs in which people pay fixed weekly or monthly subscription fees in return for shares of locally grown organic produce harvested throughout the season.

The increasing importance of locally produced food and beverage products is revealed in county data. Lammers (1997) reports that food and fish processing in Humboldt County (where Arcata is located) was one of the strongest areas of county job growth in the 1990s, and 1996 employment was nearly as large as that in the traditional industries of agriculture, forestry, and fisheries.

The city of Arcata has also created a Tourism Taskforce that has developed a strategy of promoting ecotourism. The Humboldt/Arcata Bay complex represents the largest embayment between San Francisco and the mouth of the Columbia River; it is one of the most pristine bays in California, and thus is ecologically very important for bird migration. Hence, in addition to producing approximately 70 percent of all the oysters sold in California (just as in Willapa Bay, mariculture creates a market-based incentive to protect water quality), the bay also offers unique birding opportunities, and so an *ecotourism* project of attracting birders has been a central goal of the Tourism Taskforce. Finally, the city of Arcata operates an industrial park that provides infrastructure for the Foodworks facility as well as outdoors-oriented clothing and similar light manufacturing. As a result of these efforts, Arcata's economy has become more diversified, and support of local entrepreneurs has increased economic vitality, created a higher degree of self-reliance, stemmed income leakages caused by reliance on imports, and triggered substantial employment opportunities within the community.

The Cogtong Bay Mangrove Management Project

In August 1992, the World Wildlife Fund (WWF) and the International Center for Research on Women (ICRW) studied mangrove management in Cogtong Bay, which is on the island of Bohol in the Philippines. The results of this study are reported by Mehta (1996), whose report is summarized below. Mangrove systems act as nurseries and spawning areas for many animals, as erosion control, and as vital sources of food and fuelwood for people. Approximately 70 percent of the mangroves have been cut down or converted to fish farms. In 1990, the Philippine government empowered sustainable local community management of nonwilderness mangrove systems, one of which was Cogtong Bay. In Cogtong, Bay 1,300 of the original 2,000 hectares of mangrove swamp remain, with the rest converted to fish farms. Approximately 52,000 people live in the Cogtong Bay area, and per capita income is $228, less than one-half that of the Philippines as a whole, and wild fish yields were falling as mangroves were being cut down. Mehta reports that a disproportionate level of the largely illegal mangrove logging was being conducted by wealthy and politically well-connected entrepreneurs, which was undermining the sustainability of local communities.

The goal of the management project was to help the local people better control and protect their coastal mangrove resource, to promote sustainable resource use, and to improve the economic well-being of local people. Mehta reports that the plan was to (1) organize eight Cogtong Bay communities into resource self-governance organizations, (2) rehabilitate 400 hectares of mangrove forest, (3) install artificial coral reefs to replace those that had been destroyed, (4) begin a locally operated oyster and mussel mariculture operation to boost local incomes, (5) limit illegal fishing and more sustainably manage the fishery resource, and (6) award 25-year individual "stewardship leases" to mangrove plots conditional on individuals keeping the plots under mangrove cover. While only a fraction of the target number of reefs was developed, other project targets were generally reached or exceeded. The project is considered a prototype, and the Philippine government reportedly intends to place 150,000 hectares of mangroves under sustainable community management.

Sustainable Local Economic Development in South Africa

In 1994, a largely peaceful process of democratization and empowerment in South Africa resulted in the end of apartheid and the beginning of the presidency of Nelson Mandela. South Africa's parks and refuges have for many years been viewed as being among the best in the world. These parks have become some of the largest remaining refuges for elephants, white and black rhinos, cape buffalo, lions, and leopards, among others. South Africa has 17 parks, an additional five in the process of formation, as well as many provincial parks and private game reserves. Yet as Chadwick (1996) has pointed out, the South African government must also provide for the basic needs of the very poor, mostly black, people of South Africa, including medical care, water and sanitation, housing, and schools. Unemployment is estimated to be 40 percent, and South Africa's population is growing rapidly. How can park protection be made consistent with the pressures for economic development?

Part of the solution may lie in ecotourism and in finding ways of bringing the economic benefits of ecotourism to the rural communities adjacent to these wildlife refuges. Piet du Plessis, South Africa's chief of tourism, pointed out that 730,000 people visit Kruger National Park annually, and that 77,000 of them were from overseas, compared to 56,000 when the international boycotts were still in effect prior to independence. Nationwide, the number of overseas visitors increased 52 percent from 1994 to 1995, and is expected to inject $40 billion into the South African economy over the next five years. The substantial income generated by Kruger National Park subsidizes other less well-known national parks that nevertheless harbor substantial biodiversity. Kruger and many other parks are fenced—what Chadwick (1996) refers to as a form of ecological apartheid—keeping local people from poaching and protecting local people from predators and their livestock from communicable diseases.

Perhaps most important is the work that is being done in linking the ecotourism income generated by the national parks to the welfare of local communities. Chadwick (1996) quotes park employee Chris Marais as saying "[T]he old idea of how to run a park was: Put up a BIG fence, get BIG guns, and keep the neighbors and their cattle OUT. . . . The new idea is to build support by making sure those neighbors benefit as much as possible from being next door." First, since independence, local chiefs are now empowered to meet with park staff to discuss common concerns. People displaced since 1913 can seek restitution. Most of Kruger Park's 2,700 employees are from the local communities. As Chadwick (1996) points out, "[T]he staff has established medical clinics, assisted with irrigation projects, and arranged to purchase local crafts and produce to sell in park stores. Neighbors pay only a nominal entrance fee now, and drivers of local bush taxis have been trained as tour guides" (p. 23). A portion of income from KwaZuluNatal parks is shared with local villages and communities. Chadwick reports that local villagers are considering establishing private wildlife reserves. Many local people retain traditional rights to gather building materials and some food, and some are developing camping facilities and guided tour programs. Since 1979, private reserves and game farms have increased from less than 2 million acres to more than 16 million. Most big South African parks are considered by their managers to be at carrying capacity, and many surplus animals go to private hunting reserves, where a rhino, for example, can generate $15,000 to over $40,000 in income. Other private reserves are primarily focused on attracting ecotourists.

The South African government recently passed up the opportunity to develop an estimated $3 billion in titanium, rutile, and zircon from the coastal dunes of St. Lucia Wetland Park, opting instead for preservation and ecotourism. This provides a strong indication of the commitment that South Africa appears to have to its national parks and sustainable development principles.

Moving Toward Sustainable Urban Planning in Curitiba, Brazil

The capital of the state of Paraná in Brazil, Curitiba has grown from a population of 300,000 in 1950 to over 2 million in 1990. During that time, Curitiba's economy has shifted from an agricultural base to one of industry and commerce, yet the usual results of such rapid change in developing countries—high unemployment, squatter settlements, congestion, and environmental degradation—have occurred to a much smaller extent than in similar cities in Brazil. Herbst and Allor (1992) argue that Curitiba is a living laboratory for extensive public transportation, floodplain parklands, citizen participation, and investment in appropriate technologies such as bicycle and pedestrian access. This experiment was initiated by Mayor Jaime Lerner in the late 1960s. During rapid growth in the 1970s, a public transportation system was already in place, and so growth occurred along a rationalized five-spoke public transportation network rather than the sprawl associated with private automobile transportation.

According to Herbst and Allor (1992), three-quarters of all commuters are reported to use public transportation, and so per capita fuel consumption is 25 percent lower than in comparable Brazilian cities, and the city has one of the lowest rates of ambient air pollution. City officials purchased land for conveniently located low-income housing prior to industrial and transportation construction when land was still relatively inexpensive. People wishing to build beyond the normal height limit pay a fee that goes into a low-income housing subsidy fund. Curitiba has a Free University for the Environment, providing practical short courses for families, builders, shopkeepers, and others, which are a prerequisite for certain jobs, yet many take the courses voluntarily. Some 70 percent of households sort recyclable materials for collection, and employment opportunities are created for low-income people through labor-intensive reuse/recycling programs. To limit illegal dumping, low-income people can exchange garbage for free bus tokens or surplus food. Cape Town, South Africa, is reportedly following the Curitiba model.

Summary

- We have seen two different dimensions of sustainable local community development. One focuses on the community's relationship with natural resource systems that are vital to the prosperity of the local community. This offers a model of traditional local community sustainability. Ostrom and her followers argue that economic, political, and social institutions (rule systems) are central determinants of sustainable and long-enduring community-based CPR governance systems. These systems are based on inclusive, democratic policy processes, common visions of equitable ways of allocating work inputs and resource units harvested from the commons, effective monitoring and enforcement schemes, and an adaptability to changing conditions.
- In industrialized countries, local communities must contend with free migration and extensive regional, national, and international trade, and the traditional approach must be somewhat modified. In this context, the conventional goal has been to promote job and income growth by attracting and keeping large export-oriented firms—the export-base development strategy. Because of easy migration, however, local job-creation policies have the long-term effect of increasing population size with no guarantee of more than a transitory reduction in unemployment. Moreover, bidding for

big export-oriented business enterprises can be costly and will expose the community to the risk that the big enterprise will close, which also gives the big firm leverage to coerce the local community.

- Promoting smaller-scale local business to produce goods to replace those imported from outside the community—the import-substitution development strategy—offers an alternative to the export-base approach that has the benefits of diversifying the local economy against the risk of one firm closing, reducing income leakages from the community, promoting the democratic process, and limiting the costly tax abatement and other giveaways that are the price of attracting export-base industry. If other communities are pursuing the export-base strategy, then imports may have a cost advantage over the same goods produced by smaller local businesses, making the import-substitution strategy difficult. This problem can be reduced if local people are willing to pay a modest price premium for locally made goods, and the import-substitution strategy may work best for relatively isolated communities.
- Local economic development can also focus on growing the natural, human, and human-made capital stocks in the community, thus increasing the flow of benefits to the community. Examples include education and training programs to improve the income-generating potential of local people, improved telecommunications infrastructure to promote decentralized cyber-commuting, promotion of farmers' markets (and thus local organic agriculture), and improving the noncommercial aspects of local communities such as parks, open spaces, and the arts.

Review Questions and Problems

1. List the conditions that are required for local communities to utilize local natural resources sustainably. For each condition that you list, explain the way that resource degradation may result if that condition is not met.
2. From the list provided below, access one of the Internet sites containing case studies. Find a case study of sustainable or conservation-based economic development, and write a one-page summary of the case. To what extent were the principles of sustainability integrated as elements of the development project or strategy? How successful was the project or strategy, and why?
3. Devise a sustainable economic development plan for the town that you live or grew up in. Explain how your plan is consistent with environmental sustainability and also with improving the economic well-being of people in the community. What sorts of economic activities are most appropriate for your community and why?

Internet Links

Alliance for National Renewal (http://www.ncl.org/anr/): A coalition of over 200 national and local organizations dedicated to the principles of community renewal.

Change Communications Community Development Links (http://www.change.org/links.htm): Lots of interesting material, including case studies, relating to sustainable local economic development.

Collaborative Learning Circle (http://id.mind.net/~clc/): The Collaborative Learning Circle represents a wealth of experience in community development and sustainable resource management practice, made up of 17 organizations from throughout the Northern California/Southern Oregon bioregion.

Community Stewardship Exchange (http://www.sonoran.org/): The Sonoran Institute is dedicated to promoting community-based strategies that preserve the ecological integrity of protected lands and also meet the economic aspirations of adjoining landowners and communities.

Exploring Conservation-Based Development (http://www.explorecbd.org/): Glossary, case studies, tools, and much more for those interested in conservation-based development.

Mangrove Rehabilitation and Coastal Resource Management Project of Mabini-Candijay: A Case Study of Fisheries Co-Management Arrangements in Cogtong Bay, Philippines (http://www.co-management.org/wp33cont.htm): January 1998 article by B. Katon, R. Pomeroy, M. Ring, and L. Garces, provided by the Fisheries Co-Management Internet site.

Rogue Institute for Ecology and Economy (http://www.rogueinstitute.org/): Engaged in the task of bridging the divide that our twentieth-century concept of development created between ecological and economic priorities. This southern Oregon organization's focus is on restoring and sustaining healthy forest ecosystems, rural career opportunities, and thriving communities.

Sustainable Urban Neighborhoods (http://www.louisville.edu/org/sun/): Material relating to economic and community development in urban areas.

Willapa Alliance (http://www.willapabay.org/~alliance/): Offering a nice example of community-based sustainable economic development, the mission of Washington's Willapa Alliance is to enhance the productivity and health of the Willapa area's unique watershed by building community capacity to steward the ecosystem and to create sustainable economic opportunity.

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Glossary

Absolute Resource Scarcity (chapter 5). Exists for those natural resources (or elements of the ecosystem) that have no substitutes and whose productivity cannot be enhanced by way of technology. An element of traditional Malthusian models of resource scarcity.

Acid Rain (chapter 10). Sulfur dioxide and nitrogen oxide emissions react with water droplets, oxygen, and various oxidants in the atmosphere, usually in cloud layers, to form solutions of sulfuric and nitric acid. Rainwater, snow, fog, and other forms of precipitation bring these acidic solutions into soil, streams, lakes, and rivers, lowering the pH of these soils and water bodies and damaging terrestrial and aquatic ecosystems.

Appropriation Externality (chapters 5 and 15). Occurs when the act of harvesting resource units from a common-pool resource by an appropriator subtracts from what is available to others, or results in damage to the current and/or future productive capacity of the resource. Therefore, appropriation from a common-pool resource imposes negative externalities on other appropriators, which is at the core of the tragedy of the commons. See also the entry for "rule of capture externality."

Arbitrage Opportunity (chapter 12): A difference in prices in different markets that cannot be entirely accounted for due to differences in shipping and transaction costs, and which therefore promotes trade. Entrepreneurs have incentive to export products from low-price to high-price markets. Therefore, trade tends to equilibrate prices across markets. For example, if apparel is cheap in China relative to the United States, then entrepreneurs will have an incentive to export apparel from China to the United States.

Likewise, if alcohol taxes are considerably higher in one state than in another, then alcohol will tend to be smuggled from the low-tax state to the high-tax state.

Average Effort Cost (chapter 5). Total cost divided by total effort applied to resource harvest.

Average Revenue Product (chapter 5). Total revenue divided by total effort applied to resource harvest.

Benefit/Cost Analysis (chapter 6). An analytical technique that guides policymakers by computing the present discounted value of benefits and costs for each of a set of different policy alternatives. An application of utilitarianism.

Biodiversity (chapters 12 and 13). Refers to the number of different species living in a particular ecological system.

Buyers (chapter 3). Those market participants who exhibit a willingness to pay for a certain number of units of a good or service offered through some form of market process. This willingness to pay reflects a combination of a preference for the good and an ability to pay.

Cap-and-Trade System (chapter 9). A regulatory system in which overall pollution emissions are capped, and tradable quota shares are assigned to polluters. The EPA's Acid Rain Program features a cap-and-trade system for sulfur dioxide allowances.

Capture Theory of Regulation (chapter 7). Based on the work of George Stigler and Sam Peltzman, the argument is that firms are able to form a more effective interest group than consumers or other more diffuse interests because each firm has a lot at stake, and small numbers makes firms easy to organize. Therefore, the interest group representing firms captures the regulatory process. This demand-side theory does not address the supply of regulation.

Cartel (chapter 3). A group of colluding sellers that attempt to coordinate their behavior so as to collectively act like a monopolist.

Categorical Imperative (chapter 2). Presents an action as being of itself objectively necessary, or intrinsically right, without regard to any other end that may or may not result from the action.

Coase Theorem (chapter 6). Named after economist Ronald Coase, the Coase theorem starts from the premise that a complete set of private property rights can be assigned to aspects of the environment, that polluters and those harmed by pollution can negotiate to resolve pollution problems at very low cost, and that "free rider" effects among multiple parties on either side of the negotiation are minimal. Under these conditions the central finding is that private parties can negotiate a solution equally as efficient as that which would result from more centralized regulatory processes using benefit/cost analysis.

Common-Pool Resource (chapters 5, 7, and 15). Those resources such as groundwater basins, rivers, marine fisheries, and community forests for which (1) it is difficult to exclude multiple people from appropriating from the resource, and (2) the resource units appropriated by one are no longer available to others. Contrast with "private goods" and "pure public goods."

Common Ownership (chapter 4). Also known as *common property* or *communal property.* The property rights of access, withdrawal, management, exclusion, and alienation are held in common by a group of individuals. Examples include communal farms, cooperative processors, wholesalers and retailers, and recreation facilities in a condominium development.

Comparative Advantage (chapter 12). In economics, the law of comparative advantage states that people (and by extension firms, regions or countries) should specialize in those activities for which their productivity advantage is greatest, or their productivity disadvantage is least, relative to potential trading partners. As a result, the trading party with the lowest opportunity cost of producing something is said to have a comparative advantage in producing it. Comparative advantage answers the question of what people, firms, regions, or countries should specialize in producing.

Consequentialism (chapter 2). The moral worth of actions or practices is determined by the consequences of the actions or the practices.

Conservation-Based Development (chapter 11). Refers to programs and policies that help entrepreneurs succeed in developing viable businesses that are environmentally sound and make a positive contribution to their local community.

Conservation Easements (chapter 4). A landowner sells a portion of her property right having to do with the right to develop or otherwise diminish the conservation characteristics of her land. The landowner can still engage in certain activities such as livestock grazing or selective timber harvest, but the owner of the conservation easement can sue the landowner for encroachment on the easement if the landowner engages in an activity that diminishes the conservation characteristics of her land. These easements are permanent transfers of rights that run with the land.

Consumer Surplus (chapter 3). The gain from trade that goes to buyers when the maximum amount they are willing to pay for something exceeds the price that they have to pay. Geometrically, it is the area between the demand curve and the price line in a supply/demand diagram. The experience of finding a bargain at a garage sale is an example of consumer surplus.

Contingent Valuation Method (chapter 6). Involves the use of survey questionnaires to elicit hypothetical willingness-to-pay information regarding alternative management practices or other contingencies, usually affecting environmental or ecological resources that are not traded in markets and so do not have a market price to provide an indication of value.

Cultural Capital (chapter 11). Refers to the stock and functional integrity of the body of stories, visions, values, history, language, and myths shared by people that provide the framework for how people come to view the world and their proper role in it. A source of the shared values that determine the nature of economic systems and the relationship individuals and communities have with the natural environment.

Deadweight Loss (chapter 4). A type of negative gain from trade that occurs when either too much or too little of a good or a service is exchanged in a market. Deadweight loss occurs in association with market failures, such as when pollution accompanies market transactions, or when there is a monopoly or cartel, or when consumers are misinformed about product quality. When there is deadweight loss, the total gains from trade in a market are not maximized, and so the market features an inefficiency that may justify some form of government regulatory intervention.

Decentralized Markets (chapter 3). When resource allocation occurs as a consequence of a set of individual price-mediated transactions rather than centralized allocation decisions made by government, decentralized markets result. Decentralized markets are a key element of capitalist systems.

Demand Curve (chapter 3). A graphical representation of the inverse relationship between price and quantity demanded. Points along a demand curve represent buyer willingness-to-pay values. See also the "buyers" entry.

Dematerialization (chapter 12). Refers to a process of reducing the throughput of physical resources and energy required to produce a given dollar of gross domestic product.

Demographic Transition (chapter 12). A theory that relates the stages of the industrialization process to growth rates in population. Stage 1, prior to industrialization, features high birthrates and death rates, and thus low growth rates. Stage 2, the initial stage of industrialization, features a sharp drop in death rates but persistently high birthrates, perhaps because medical technology reduces child mortality, but cultural values related to childbearing are slower to adapt. Much higher population growth rates are experienced in stage 2. Stage 3, the fully industrialized stage, features low birthrates and death rates, and thus a return to low population growth rates.

Deontological Ethics (chapter 2). Theories of action based on duty or moral obligation. Actions are judged by their intrinsic rightness and not by the extent to which they further one's own goals or aspirations.

Deterrence (chapter 8). In the context of promoting compliance with environmental and resource management law, a risk-neutral firm will be deterred from violating the law when the expected penalty exceeds the cost savings or revenue gains from being out of compliance. The expected penalty is the penalty or sanction (such as a fine) weighted by the probability of the violator being detected and penalized.

Derby (chapter 5). In the context of marine capture fisheries, a *derby* is the race for fish that occurs when a total allowable catch (TAC) is set, and fishers race with one another to catch fish before the TAC is met and the fishing season ends.

Direct Compliance Costs (chapter 6). The cost of environmental regulation can be divided into direct and indirect costs. *Direct compliance costs* include pollution abatement and expenditures by firms, consumers, and government, as well as opportunity costs that can be attributed directly to regulation.

Discount Rate (chapters 5, 6, and 12). The rate at which the present value of increasingly distant benefits or costs shrinks. Discount rates are embodied in interest rates charged on borrowed money and other financial investments in financial markets.

Dose-Response Relationship (chapter 6). In the case of risk assessment, the dose-response relationship for a specific pollutant or human activity describes the association between exposure and the observed response (health or ecological effect).

Dynamic Efficiency (chapter 5). A criterion for evaluating projects or decisions that generate a stream of benefits and/or costs into the future. When a set of alternatives is being considered, the dynamically efficient alternative generates the largest present discounted value of net benefits, profit, or surplus.

Ecolabels (chapter 14). Programs designed to inform consumers of the social and environmental impacts of the goods and services they purchase. Ecolabels are most effective when an independent third-party agency establishes the standards and evaluates the extent to which products adhere to those standards. An example is the SmartWood certification for sustainably harvested wood products.

Ecological Tax Reform (chapters 12 and 14). The reform of public finance in which taxes are shifted from productive activities such as income and employment to destructive activities such as pollution emissions and the depletion of natural resources. Because anything that is taxed is discouraged, ecological tax reform can be a revenue-neutral way of promoting desirable activities and discouraging polluting activities.

Economic Development (chapter 13). The process of improving the well-being of society.

Economic Growth (chapter 12). The rate of increase in real (inflation-adjusted) gross domestic product (GDP).

Economic Rationality (chapter 1). When a choice is taken from among competing options that yields anticipated net benefits that exceed the opportunity cost.

Economics (chapter 1). The study of how scarce resources are allocated among competing uses.

Economies of Scale in Production (chapter 12): These occur when the average cost of producing a unit of a good or a service declines as more and more is produced at a given factory or office. For example, automobile and aircraft production features economies of scale in production because of the extensive amount of capital equipment required to produce cars and airplanes. The average cost of manufacturing a car or an airplane declines as more and more are produced, because the cost of the capital can be spread out over more and more units.

Ecosystem Services (chapters 5, 11, and 13). As Robert Costanza and his colleagues have observed, ecosystem services consist of flows of materials, energy, and information from natural capital stocks that combine with manufactured and human capital services to produce human welfare.

Efficiency (chapters 3 and 6). Generally refers to the condition of producing something of value with a minimum of waste. Efficient *resource allocation* is realized under market exchange when all the available gains from trade are realized, while efficient *production* occurs when goods or services are produced at minimum cost. A proposed social policy is *Pareto-efficient* when it makes some people better off and nobody worse off in comparison to the status quo or some other policy option. In contrast, a proposed social policy is *potentially* Pareto-efficient (or *Kaldor–Hicks-efficient*) when it generates an increase in total net social benefits compared to the status quo and other policy options, and thus the potential exists for those made better off to compensate those made worse off.

Effluent Charges (chapter 9). Fees or taxes charged on the emission of a pollutant. Pollution taxes are a type of effluent charge.

Embedding Effect (chapter 6). In the context of the contingent valuation method, the embedding effect occurs when willingness-to-pay responses for a particular good (protecting a mountain lake) are approximately equal to the willingness-to-pay responses for a more inclusive good (protecting an entire mountainous region that includes the lake among other features). When it occurs, the embedding effect may indicate the nonexistence of individual preferences for the good in question, and the failure of respondents to consider the effects of their budget constraints in hypothetical willingness-to-pay surveys.

Emissions-Trading Programs (chapter 9). Started in 1976, these are regional, state-controlled programs designed and operated in cooperation with the Environmental Protection Agency. To understand the concept, see the “marketable pollution allowance systems” entry.

Equimarginal Principle (chapters 4, 6, 8, and 9). The equimarginal principle simply states that an optimal allocation occurs when marginal benefit equals marginal cost.

Ethics (chapter 2). A branch of philosophy that is concerned with moral duty and ideal human character.

Existence Value (chapter 6). See the entry for “nonuse value.”

Export-Base Model of Economic Development (chapter 15). Local economic growth is fostered when communities attract firms that produce goods and services that are then exported outside the community. These exports generate income injections into the community, which offset income leakages out of the community due to the purchase of goods imported into the community.

Exposure Assessment (chapter 6). In the case of risk assessment, exposure assessment involves an estimation of the quantity of the pollutant that people breathe, drink, absorb through the skin, or are otherwise exposed to in a period of time. Exposure assessment also includes an estimate of how many people are exposed.

Extended Producer Responsibility (chapter 14). Regulatory programs that make producers rather than consumers and municipal governments responsible for reusing, recycling, or disposing of packaging and worn-out products. Extended producer responsibility (EPR) programs give producers an incentive to design products with less waste and for easier and less costly reuse, disassembly, and recycling. Notable examples include the packaging take-back and recycling legislation in Germany, the Netherlands, Austria, Switzerland, and France, as well as end-of-life legislation and voluntary agreements concerning a number of complex products such as cars, batteries, electronic and electrical appliances.

Externality (chapter 4). Positive externalities are external benefits generated from production and exchange, and enjoyed without payment by members of society. For example, when parents pay to vaccinate their children against infectious disease, they create an external benefit—the reduced likelihood of epidemic—that is shared by many in society. Negative externalities are external costs generated from production and exchange and borne without compensation by members of society. For example, when firms can avoid costly cleanup by polluting, they create an external cost—the harms created by their pollution—that is shared by many in society.

Fertility Rate (chapter 12): The average number of children produced by a woman in a country. The fertility rate has been declining worldwide over the last 50 years, and is below replacement in almost half.

Fishing Effort (chapter 5). The deployment of fishing inputs (vessel, gear, labor). May be measured as the dollar value of total inputs, or as the aggregate amount of time that inputs are deployed, with adjustments made for differences in the productivity of different vessel and gear types.

Fixed Costs (chapter 6). Those costs that do not vary with the quantity that a firm produces in the short run. An example is the cost of leasing office space or renting equipment. Even if a firm shuts down production, it must still pay fixed costs in the short run.

Free Rider (chapters 3 and 6). One who enjoys the benefits of a public good or common-pool resource without paying a share of the costs of providing for or maintaining it. Voluntary contributions will fall short of providing the socially optimal quantity of a public good or a common-pool resource when there are many free riders.

Fugitive Resources (chapters 4 and 5). Those resources such as marine fisheries, groundwater basins, oil and gas fields, or stocks of fresh air having the characteristic of being difficult or impossible to fence, brand, or partition. Such resources tend to be state property, common property, or to be open-access resources rather than private property.

Gain from Trade (chapters 3, 4, and 6). The positive net benefit to market participants that occurs as a consequence of trade. The gain to consumers, known as "consumer surplus," is the difference between the maximum amount that consumers were willing to pay (consumer valuation) and the market price they actually have to pay. The gain to producers, known as "producer surplus," is the difference between market price and the minimum amount that sellers are willing to accept (producer valuation). Resources are said to be efficiently allocated in a market when all possible gains from trade are realized.

Green GDP (chapter 13). An adjustment to gross domestic product (see the "gross domestic product" entry below) that takes into account declines in nonrenewable resources, expenditures on pollution control, and external costs due to pollution. A method of integrating environmental impact into GDP.

Greenhouse Effect (chapter 10). Certain gases such as carbon dioxide, nitrous oxide, methane, and chlorofluorocarbons allow visible light to pass through but block much of the resulting heat that would otherwise radiate from the warmed surface of Earth and out into space. Thus, these atmospheric gases act like the clear walls of a greenhouse, creating a warmer environment than would otherwise exist. Human activity has increased the atmospheric concentration of carbon dioxide, a key greenhouse gas, by about 36 percent in the last several hundred years, and this process is forecast to accelerate.

Gross Domestic Product (GDP) (chapter 13). The value of the final goods and services produced in a country in a given year.

Hazard Identification (chapter 6). In risk assessment, hazard identification refers to identifying the health problems caused by the pollutant. In the case of human health risk assessment, hazard identification uses both animal and human studies to establish the likelihood that a pollutant will generate harm to human health.

Hedonic Regression Method (chapter 6). A method used to determine the value of aspects of the environment not traded in markets and thus lacking a price to indicate value. This method uses regression analysis, a type of statistical analysis, to infer the value of environmental qualities that are bundled together with things that are traded in markets. For example, the price of residential housing reflects not only the characteristics of the house, but also the community and natural environmental qualities of the place where the house was built. Hedonic regression analysis can be used to assign prices to units of these environmental qualities such as lower crime rates, views, distance to a park or green space, open space, or clean air.

Hotelling Rent (chapter 5). Also known as *scarcity rent* or *resource rent*, it is economic profit that can be earned and can persist in certain natural resource cases due to the fixed supply of the resource. Owing to fixed supply, consumption of a resource unit today has an opportunity cost equal to the present value of profit from selling the resource in the future. This opportunity cost limits current supply, which in turn elevates current price above marginal cost, creating the rent. Under "tragedy of the commons," current Hotelling rents are dissipated because individual resource appropriators cannot find a way to limit current supply for future sale.

Hotelling's Rule (chapter 5). In equilibrium, the marginal Hotelling rent (P – MC) in the current period will equal the present discounted value of the marginal Hotelling rent in future periods. If the present discounted value of marginal Hotelling rent was larger in the future than in the present, then it would be profitable for producers of the resource to reduce sales today in order to have more to sell in the future. When Hotelling's rule is satisfied, the market is dynamically efficient, meaning that the present discounted value of the total gains from trade summed over all the years of resource production is maximized.

Human Capital (chapters 11 and 13). The stock of knowledge, skills, and capabilities of people that can be deployed to create a flow of useful work for community and economy.

Human-Made Capital (chapters 11 and 13). The stock of technologies, tools, equipment, productive facilities, and inventory of products that economists traditionally think of as the capital stock. Also known as *created capital* or *constructed capital*, or occasionally *financial capital*.

Import-Substitution Model of Economic Development (chapter 15). An alternative to the export-base model (see the "export-base model of economic development" entry above). Instead of offering tax giveaways to attract big exporting firms, which will then have disproportionate power over the local community, local incomes and jobs can be enhanced by promoting local small businesses that produce local substitutes for imported goods, which would otherwise drain income from the community.

Incentive Regulation (chapter 9). Regulatory schemes that use prices, taxes, subsidies, and other instruments to align individual incentives with the common good. This form of regulation controls pollution indirectly through incentives rather than by way of direct controls such as caps on emissions and technology-forcing rules.

Indirect Costs (chapter 6). Changes in production and production costs due to environmental regulation can result in additional costs such as product market distortions, changes in market concentration, and reduced rates of economic growth.

Individual Transferable Quotas (chapter 5). In the context of a fishery, individual transferable quotas (ITQs) are shares of a total allowable catch (TAC) allocated to fishers. Initial quota allocations are usually based on historical landings. Quotas can be traded among fishers, and a competitive quota market can be expected to allocate quota to its highest-valued use. The ITQs are commonly used in fisheries that are overcapitalized and that have experienced problems associated with a race for fish (derby). Market forces resolve overcapitalization and promote efficiency by concentrating larger quota shares on a relatively small number of vessels. Fishers need not race for fish because they can fill their quota at any time during the season opening.

Inflation (chapter 12). The rate at which the overall price level rises over time. Inflation can be measured in the overall economy or for particular sectors such as healthcare or higher education.

Invisible Hand (chapters 5 and 7). A term associated with economics pioneer Adam Smith that refers to the efficient way that well-functioning competitive markets coordinate the complex and interdependent allocation of scarce resources in an economy without the guiding hand of economic planners.

Kaldor–Hicks Criterion (chapters 2 and 6). See the “efficiency” entry.

Law of Demand (chapter 3). Demand curves are downward-sloping.

Law of Diminishing Marginal Returns (chapter 4). In the short run some production inputs are fixed, typically capital (e.g., the lease on a production or sales facility). Therefore, to increase output in the short run, the firm must add more and more variable inputs such as labor. Eventually the fixed input becomes congested with the variable input (e.g., too many cooks in the kitchen; too much irrigation water or fertilizer in the field). When this congestion occurs, the marginal productivity of a unit of the variable input (e.g., labor) declines. For example, if a workplace is congested, then the next worker hired will make a smaller contribution to output than one who preceded her.

Law of Supply (chapter 3). Supply curves are upward-sloping.

Marginal Cost (chapter 4). See the entry for "marginal private cost" below.

Marginal Effort Cost (chapter 5). The increase in total cost from applying an additional unit of effort to resource harvest.

Marginal External Cost (chapter 4). The increase in total external cost (costs borne by society in the form of pollution harms) that occurs as a consequence of a small (one-unit) increase in output produced by a firm.

Marginal Net Benefit (chapter 6). Marginal benefit–marginal cost. When marginal net benefit is positive, then a small incremental increase in pollution control or other policy activity contributes to a larger total net benefit.

Marginal Private Cost (chapter 4). The increase in total private cost (borne by producers) that occurs as a consequence of a small (one-unit) increase in output produced by a firm.

Marginal Revenue Product (chapter 5). The change in total revenue from applying an additional unit of effort to resource harvest.

Marginal Social Cost (chapter 4). The increase in total social cost (borne by both producers and other members of society) that occurs as a consequence of a small (one-unit) increase in output produced by a firm. Marginal social cost equals the sum of marginal private cost and marginal external cost.

Marginal Utility of Money (chapter 6). The increase in a person's total utility or satisfaction that occurs as a consequence of a $1 increase in income. Economists generally assume that the marginal utility of money, like the marginal utility of most other valuable things, is positive but tends to become smaller as total income rises. Thus, a billionaire would have a smaller marginal utility of money than someone living in poverty.

Market (chapter 3). An institution that coordinates trade between buyers and sellers. These institutions determine how buyers and sellers communicate, how prices are set, and how money is exchanged for goods or services.

Market Capitalism (chapter 3). A socioeconomic system based on the use of a complete set of decentralized markets to allocate scarce resources, goods, and services. In this system, human-made capital is privately owned by individuals, and production and employment decisions are decentralized and thus made by firms. This system is in sharp contrast with centrally planned allocation of scarce resources and government (or community) ownership of human-made capital under socialism or communism.

Market Equilibrium (chapter 3). Occurs at a price at which the quantity of a good or service demanded by buyers is just matched by the quantity supplied by sellers, meaning that neither a shortage nor a surplus occurs.

Market Failure (chapter 3). Occurs when one or more of the conditions required for a well-functioning competitive market is not met in a substantial way. Examples include monopolization or cartelization of markets, the presence of significant positive or negative externalities, or poorly informed buyers.

Marketable Pollution Allowance Systems (chapter 9). These systems are designed to work in conjunction with overall emissions-control schemes, with the objective being to reduce the cost of regulatory compliance. Polluters are issued quotas (usually a fraction of historical emissions levels), which represent their total emissions allowance under the emissions-control scheme. If some firms can further reduce their emissions, and if their cost of emissions control is much lower than for others, then trade in allowances will result in the firms with lower emissions-control costs selling allowances to firms with higher emissions-control costs. Allowances trade shifts cleanup to firms with lower cleanup costs, reducing the industrywide cost of compliance with an overall emissions reduction target.

Maximum Sustained Yield (chapter 5). The maximum number or quantity of resource units that can be harvested without damaging the productive capacity of the resource stock.

Monopoly (chapter 3). The condition that exists when there is a single seller that dominates a market. When monopolies are protected from entry by rival firms, the incentive for profit maximization results in the monopolist supplying less to the market than would otherwise happen under competitive conditions, which causes price to be higher than under competition.

National Income and Product Accounts (chapter 13): Accounts that are used to measure the total income and output of a national economy. Gross domestic product (GDP) is derived from data from the national income and product accounts.

Natural Capital (chapters 11 and 13). The stock of natural resources, together with the components and the structural relationships in Earth's ecosystems, that taken together, serve as the foundation for life on Earth. From the stock of natural capital flows the annual harvest of natural resources, ecosystem services, sink functions, and other benefits from a healthy environment.

Negative Externality (chapters 3 and 4). See the "externality" entry.

Network Externalities (chapter 5). Positive network externalities occur when network use by one entity creates benefits for others. A classic example is the benefit of having everyone on a common telephone network, as opposed to having people on different telephone systems lacking interconnectivity. Negative network externalities occur when network use by one entity creates costs to others. For example, on electric transmission networks ("grids"), excessive withdrawals by one entity can create system problems such as blackouts on others. Similarly, excessive withdrawals of natural gas from a pipeline network can reduce system pressure and impair deliveries to other network members.

Nonrenewable Resource (chapter 5). A class of resource having the characteristic that the overall stock cannot replenish itself within the human time frame.

Nonuse Value (chapter 6). Also known as "passive-use values" or "existence values," nonuse values reflect the value that people assign to aspects of the natural environment that they care about but do not use in a commercial, recreational, or other manner. For example, someone might value the existence of grizzly bear habitat in Alaska, but have no interest in actually visiting such wildland habitat. Such "existence values" are controversial because they are difficult to measure.

Normative Economics (chapter 2). Identifies the economic elements of how things should be, based on a particular set of norms or standards, as opposed to objectively describing the current economic state of affairs.

Open Access (chapters 4 and 5). A state of affairs that exists when there are no property rights systems recognized that constrain access to a resource or withdrawals of resource units, typically for a natural resource. Tragedy of the commons is the anticipated outcome when self-interested appropriators harvest resource units from an open-access common-pool resource.

Opportunity Cost (chapters 1 and 6). When a scarce resource, good, or service is allocated to one use, the opportunity cost of that allocation represents the net value of the best alternative that was lost.

Opportunity Cost of Capital (chapter 12). When a firm is considering a capital investment, such as expanding production capacity, the investment is anticipated to generate a flow of additional net income. The opportunity cost of that capital investment is the net income that can be earned by investing the money in some other income-generating asset, like stocks, bonds, or alternative projects. For example, if the next best use of invested capital is to buy U.S. Treasury Bonds paying a 7 percent annual return, then every dollar invested in a particular capital project has an opportunity cost of generating a 7 percent return each year.

Pareto Efficiency Criterion (chapters 2 and 6). See the "efficiency" entry.

Pigouvian Taxes (chapter 4). A tax (named after economist A.C. Pigou) placed on firms that is equal to the marginal external costs resulting from their pollution emissions. For example, if each unit of a good or service produced by a firm generates $20 in marginal external cost, then a Pigouvian tax of $20 per unit of output would internalize the marginal external cost, thereby resolving the market inefficiency caused by the presence of the negative externality.

Political Economy (chapter 7). A method of analyzing the incentives, institutions, and outcomes of governance problems.

Pollution (throughout the textbook). Harmful human-generated (anthropogenic) waste emissions that exceed the assimilative capacity (sink functions) of Earth's ecosystems.

Pollution Abatement (throughout the textbook). Reducing, eliminating, or properly disposing of unwanted human emissions or wastes that are harmful to the natural environment.

Pollution Taxes (chapter 9). Taxes placed on firms based on their pollution emissions. Unlike Pigouvian taxes, however, pollution taxes may not be designed to fully internalize external costs. In other words, pollution taxes may be greater than or less than the theoretically correct Pigouvian tax. Also see the entry for "effluent charges."

Pollution Credits (chapter 9). See entry for "tradable pollution credits."

Positive Economics (chapter 2). A method of economic analysis based on the Western scientific tradition of modeling the world and then subjecting these models to empirical test. Positive analysis seeks to explain the observable. Contrast with *normative economics*. See the "normative economics" entry.

Positive Externality (chapters 3 and 4). See the "externality" entry.

Precautionary Principle (chapters 10 and 13). Suggests that precautionary measures should be taken when evidence suggests that an activity is generating costly or irreversible harms, even if there is still some uncertainty over the extent or the mechanics of the harms.

Present Discounted Value (chapters 5 and 6). The present value of a future benefit or cost. Because people (and thus, firms as well) have positive discount rates (see the "discount rate" entry), the present discounted value of a future benefit or cost is smaller than the dollar amount of the payment in the future. The higher the discount rate, or the longer the time period before the benefit or the cost is received, the smaller the present discounted value.

Primary Market (chapter 5). In the context of metals markets, the market for metal directly smelted from virgin ore, as opposed to secondary markets made up of metal derived from recycled material.

Private Good (chapter 5). A good or service that can be excluded from other people's use. Use subtracts from the total that is available at any given time. The sort of good exchanged in markets.

Private Ownership (chapter 4). Also known as *private property.* The property rights of access, withdrawal, management, exclusion, and alienation are held by a private company, partnership, or individual owner.

Producer Surplus (chapter 3). The seller's share of the gains from trade. The area between price and a seller's minimum sales price (usually marginal cost).

Property Rights (chapter 4). In the context of natural resources and the environment, one or more of the rights of accessing a resource, withdrawing or harvesting resource units, managing a resource, excluding others from accessing the resource, and selling to someone else.

Public Choice (chapter 7). A form of political economic analysis that treats politicians as any other self-interested maximizer having an objective function that might include current and discounted future income, re-election, ideology, or power and control. Thus, the rational behavior of a politician is predicted to be in a manner that is consistent with his or her objectives, which may or may not be consistent with the public interest.

Pure Public Good (chapter 5). A good or service (1) that is used by multiple people, and (2) for which use by one does not subtract from what is available for others to use. The latter characteristic distinguishes pure public goods from common-pool resources. An example of a pure public good is public radio or public television broadcasts.

Quantitative Risk Assessment (chapter 6). Quantitative risk assessment involves four steps: hazard identification, exposure assessment, dose response, and risk characterization. Risk assessment for environmental issues often addresses impacts on human health or on animals and plants in ecosystems. Risk assessment data can then be monetized and used to indicate the value of environmental conservation and restoration in benefit/cost analysis.

Rational Choice (chapters 1 and 7). From the perspective of economics, a choice is rational if it is consistent with the objectives and preferences of those making the decision, given the available information. An allocation choice is economically rational if it is seen as yielding a benefit that exceeds opportunity cost. What is economically rational for one person may not be seen as reasonable by another.

Renewable Resources (chapter 5). The class of resources that are capable of replenishing themselves over time. Excessive harvest can deplete the reproductive capacity of a renewable resource.

Rent Dissipation (chapter 5). In the context of natural resources, dissipation of Hotelling rents occurs when current consumption rates exceed the dynamically efficient consumption rate. In the context of common-pool resources, this outcome has been described by Garrett Hardin as the "tragedy of the commons." See also the entry for "Hotelling rent."

Resilience (chapter 13). As used here, the magnitude of shocks (flood, drought, fire) that an ecosystem can withstand before being pushed from one locally stable equilibrium to another. Shifts from one equilibrium to another can cause detrimental changes in ecosystems.

Risk Characterization (chapter 6). The final step of risk assessment, risk characterization presents risk assessment results in various ways in order to illustrate how individuals or populations in human or ecological communities may be affected by pollution or other harmful human activity.

Rule of Capture (chapter 4). A part of our common law tradition, the rule of capture operates on open-access and common-property resources such as groundwater basins, oil and gas fields, and marine fisheries. The rule of capture states that resource units harvested from an open-access or a common-property resource become private property owned by the appropriator at the time the resource units are captured from the commons.

Rule of Capture Externality (chapter 5). A phrase used by some resource economists to refer to appropriation externalities.

Scarcity (chapter 1). Something is said to be scarce when, at zero price, more is wanted than is available.

Scarcity Rent (chapter 5). See the entry for "Hotelling rent."

Secondary Market (chapter 5). In the context of recyclable resources such as glass and metal, the secondary market is the market for salvaged or recycled resources, as opposed to the primary market for glass or metal produced from virgin resources.

Sink Capacity (chapter 5). The capacity of the biosphere to absorb human waste and render it harmless. Pollution occurs when human emissions exceed Earth's sink capacity.

Social Capital (chapter 11). As the concept is used by sociologist James Coleman and political scientist Robert Putnam, it refers to the stock of "civic virtues" and networks of civic engagement, involvement, reciprocity norms, trust, volunteerism, and sharing essential to democratic communities.

Social Rate of Time Preference (chapter 12). A discount rate that can be made consistent with weak-form sustainability. A key element of the social rate of time preference is the per capita growth rate in the productivity of human-made capital. If the productivity of a unit of human-made capital naturally grows at a 1 or 2 percent rate because of technological innovation, then social projects that divert money from such investments and into improving future environmental quality (enhancing future natural capital) should use a 1 or 2 percent discount rate. Under weak-form sustainability, the various forms of capital are substitutable for one another, and so the opportunity cost of investment in natural capital is the return on human-made capital. The other element of the social rate of time preference is individuals' pure preference for benefits received today rather than in the future.

Stable Systems of Regulation (chapter 7). In this "Stiglerian" situation, regulatory controls for protecting the environment are relatively unlikely to be overturned, perhaps because the regulation generates concentrated benefits to a few firms, individuals, or organizations that accordingly have a strong incentive to lobby to maintain the regulation. See the "capture theory of regulation" entry.

State Ownership (chapter 4). Also known as *government ownership*. The property rights of access, withdrawal, management, exclusion, and alienation are held by some subdivision of government. Examples include military bases, national parks and forests, and public roads, bridges, and buildings.

Status Quo (chapter 2, 6). Latin phrase for the existing state of affairs or the current way of doing things.

Strong-Form Sustainability (chapter 13). Developed from ecological theories of sustainability. Primarily focuses on protecting and enhancing natural capital. A key assumption is that declines in natural capital cannot be made up with increases in human or human-made capital.

Structural Adjustment (chapter 13). Developing countries that became saddled with enormous debt burdens from earlier ill-advised development loans were offered structural adjustment loans in return for economic and political restructuring that involved privatization of government-owned industry, reduced social spending, increased openness to foreign investment, and a focus on export-oriented production, typically of natural resource commodities. Falling commodity prices created pressure for unsustainable resource harvest, which led the Brundtland Commission of the United Nations to call for sustainable development.

Sunk Costs (chapter 7). Costs that cannot be salvaged if an activity is ended. For example, if a worker invests time and effort in learning a work routine that is highly specific to a particular employer, then the costs associated with developing workplace skills are sunk and thus cannot be salvaged if the worker quits and moves elsewhere. Such a situation gives bargaining power to the employer.

Supply Curve (chapter 4). A graphical representation of the relationship between quantity supplied and price. The supply curve for individual competitive firms is their short-run marginal private cost curve. The market supply curve is found by horizontally summing each individual firm’s supply curve.

Sustainability (chapter 11). A community’s control and prudent use of natural, human, human-made, social, and cultural capital to foster economic security and vitality, social and political democracy, and ecological integrity for present and future generations. Ecological sustainability more narrowly focuses on maintaining and enhancing ecological integrity and biodiversity, and generally on protecting Earth’s life-support and waste-sink functions.

Sustainable Economic Development (chapter 13). The Brundtland Commission defined sustainable economic development as the process of satisfying present needs without compromising the ability of future generations to meet their own needs. We can also interpret sustainable economic development as a redirection of economic development toward enhancing economic security and vitality, social and political democracy, and ecological integrity for present and future generations. Sustainable economic development generates improvements in human well-being without large increases in energy and materials throughput.

Teleological Ethics (chapter 2). A class of ethical theory in which the ethics of actions are judged by the extent to which they advance valuable ends or goals, and not by the intrinsic rightness of the actions themselves. A prominent form of teleological ethics is *utilitarianism.*

Throughput (chapter 12). The flow of materials through an economy, starting with inputs of raw materials, followed by their conversion into products and services, and ultimately their transformation into wastes of various kinds.

Total Net Benefit (chapter 6). Total benefit – total cost.

Total Surplus (chapters 3 and 4). Also known as the *total gains from trade.* The sum of consumer and producer surplus in a market.

Tradable Pollution Credits (chapter 9). Also known as *tradable emission credits*, these regulatory programs regulate emissions at the level of the individual source rather than set an overall cap on emissions. Firms that reduce their emissions below their regulatory maximum are granted credits that can be traded. These programs often allow firms to bank credits for future use. Contrast with a cap-and-trade regulatory program that sets an aggregate emission cap and allows emission quota shares to be traded among individual polluters.

Tragedy of the Commons (chapter 5). A term coined by Garrett Hardin for excessive appropriation from a common-pool resource under an open-access or a dysfunctional common-property regime. Excessive appropriation occurs because (1) each user imposes appropriation externalities on the others, and (2) governance structures that might limit appropriation to sustainable levels are inadequate or lacking. The tragedy is that the rational appropriator knows that the resource should be conserved, but nevertheless depletes the resource because resource units conserved by one will simply be appropriated by another. The tragedy of the commons leads to the dissipation of Hotelling rents and damage or destruction of the common-pool resource. Also see the entries for "appropriation externality," "Hotelling rent," "open access," and "rent dissipation."

Transaction Costs (chapters 3 and 6). The costs of making, measuring, and enforcing agreements. Often these are information costs. An example would be the cost of hiring a mechanic to inspect a used car to determine quality prior to purchase.

Travel Cost Method (chapter 6). In the context of measuring the value of aspects of the environment not traded in markets, the travel cost method assigns a dollar value to active recreational use based on observed travel costs borne by those who come to use the resource.

Use Value (chapter 6). Use value represents the utility enjoyed by people who directly use some aspect of the environment. For example, a bird sanctuary yields use value to bird watchers and to those who use the area as an open space (walking, jogging, observing the view). Likewise, a backcountry area provides use value to hunters, hikers, backpackers, and equestrians, and the ocean shore affords use value to surfers and fishers.

Usufructuary Rights (chapter 4): Certain use and withdrawal rights to property that is owned by others. For example, treaties ceding Indian lands to the federal government sometimes include clauses granting Indian tribes usufructuary rights for hunting, fishing, and gathering on the ceded lands. Likewise, "water rights" held by irrigators on navigable waterways are usufructuary rights, with the waterway itself being owned by government in a public trust capacity.

Utilitarian Ethics (chapter 2). A proposed social rule is considered utilitarian-ethical if, after adding up the utility and the disutility that the proposed rule induces on people in society, a positive net social utility is realized that exceeds that of any alternatives being considered. This rule is sometimes (imprecisely) characterized as providing the greatest good for the greatest number without regard to the intrinsic rightness of the specific acts required to achieve the desirable end.

Utility (chapter 2). The principle that judges actions according to their tendency to increase or decrease an individual's happiness.

Weak-Form Sustainability (chapter 13). A theory of sustainability that developed from economic models of growth. A key assumption is that declines in natural capital can be offset by increases in human, social, or human-made capital. In other words, one form of capital can readily substitute for another. While strong-form sustainability is concerned with the stock of each individual form of capital, weak-form sustainability is only concerned with the sum of the stocks of all forms of capital.

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