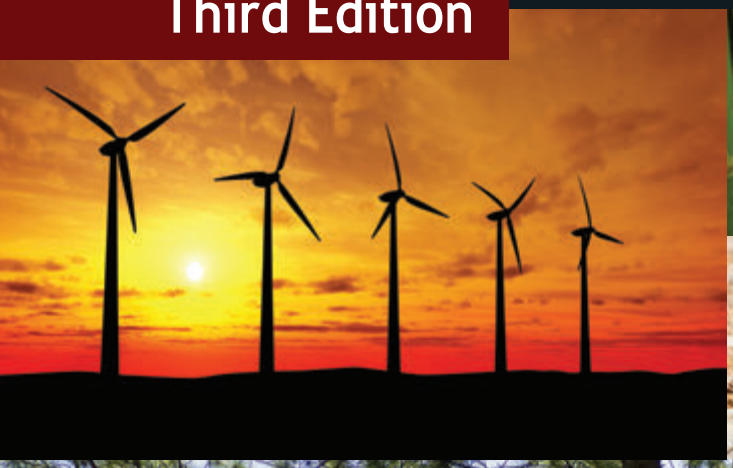
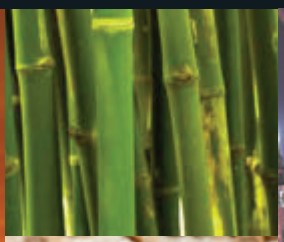
Environmental and Natural Resource Economics

A Contemporary Approach

Third Edition





Jonathan M. Harris and **Brian Roach**

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Contents

Note to the Reader

Key Terms are bolded in the text, with a sidebar definition.

All Key Terms in a chapter are listed at the end of the chapter, and the definitions are collected in the Glossary, noting the chapters in which they appear.

Preface to the Third Edition

The third edition of *Environmental and Natural Resource Economics: A Contemporary Approach* maintains its essential focus on making environmental issues accessible to a broad range of students. The text is a product of twenty years of teaching environmental and natural resource economics at the undergraduate and graduate levels. It reflects the conviction that environmental issues are of fundamental importance and that a broad approach to understanding the relationship of the human economy and the natural world is essential.

Typically, students come to an environmental economics course with an awareness that environmental problems are serious and that local, national, and global policy solutions are needed. Some students may be interested in careers in environmental policy; others in gaining an understanding of issues that are likely to be relevant in their careers, personal lives, and communities. In either case, the current importance of the topics gives the course a special spark of enthusiasm that is a heaven-sent boon to any instructor trying to breathe life into marginal cost and benefit curves.

There is a distinct danger, however, that this initial enthusiasm can be dampened rather quickly by the use of a strictly conventional approach to environmental economics. One major limitation of this approach is its almost exclusive use of neoclassical microeconomic techniques. The standard microeconomic perspective strongly implies that anything of importance can be expressed in terms of price—even though many important environmental functions cannot be fully captured in dollar terms. Also, this perspective makes it difficult to focus on the inherently "macro" environmental issues such as global climate change, ocean pollution, ozone depletion, population growth, and global carbon, nitrogen, and water cycles.

For these reasons, the authors have developed an alternative approach that draws on the broader perspective that has come to be known as ecological economics, in addition to presenting standard economic theory. In our view, these two approaches are complementary rather than in conflict. Many elements of standard microeconomic analysis are essential for analyzing resource and environmental issues. At the same time, it is important to recognize the limitations of a strictly cost-benefit approach and to introduce ecological and biophysical perspectives on the interactions of human and natural systems.

New to the Third Edition

The third edition of *Environmental and Natural Resource Economics: A Contemporary Approach* has been updated in response both to developments in the world of environmental policy and to comments and suggestions based on classroom use. New material in the third edition includes:

- a new chapter on water economics, including analysis of water demand management, water pricing, and water privatization
- a new chapter on the relationship between environmental protection and the economy, including analysis of decoupling output from resource and energy inputs and policies to promote a green economy
- new scientific evidence on climate change and a new chapter on global climate change policy, including technological potential, abatement costs, and proposals for an Earth Atmospheric Trust and Greenhouse Development Rights
- more on the application of economic valuation techniques, including evaluating new mercury regulations, valuing life, and estimating the impacts of the Gulf oil spill
- new material on "green" national income accounting, including adjusted net savings, the Genuine Progress Indicator, the Better Life Index, and environmental asset accounts
- new sections on recent population developments, including changing fertility rates, projections for 2050 to 2100, and the human ecological footprint
- changing projections for food supply and the impact of the "food crisis," rising meat consumption, and biofuels
- new data on rising prices for minerals and new projections for fossil-fuel supply limits, discussion of fossil-fuel subsidies, and the potential for a transition to renewable energy

All data series have been updated to reflect recent trends. New appendices have been added to chapters dealing with formal analysis, providing greater depth in analytical techniques.

Organization of the Text

The text is structured so as to be appropriate for a variety of courses. It assumes a background in basic microeconomics and can be used in an upper-level undergraduate course or a policy-oriented master's-level course. Part I provides a broad overview of different approaches to economic analysis of resources and environment and of the fundamental issues of economy/environment interactions. Part II covers the basics of standard environmental and resource economics, including the theory of externalities, resource allocation over time, common property resources, public goods, and valuation. Part III offers an introduction to the ecological economics approach, including "greening" national accounts and economic/ecological modeling.

Parts IV and V apply these analytical approaches to fundamental environmental and resource issues. Part IV focuses on population, agriculture, and the environment, reviewing different theories of population, giving an overview of the environmental

impacts of world agricultural systems and discussing policy responses to population and food supply issues. Part V deals with the economics of renewable and nonrenewable resources at both the microeconomic and macroeconomic levels.

Part VI provides a standard analysis of the economics of pollution control, a new chapter on the relationship between environmental protection and the economy, and two chapters that address global climate change. Part VII brings together some of the themes from the specific topics of the earlier parts in a consideration of trade and development issues.

Pedagogical Aids for Students and Instructors

Each chapter has discussion questions, and the more quantitative chapters have numerical problem sets. Key terms in each chapter are compiled in an extensive glossary. Useful Web sites are also listed. Instructors and students are urged to make full use of the text's supporting Web sites at http://www.gdae.org/environ-econ.

The instructor Web site includes teaching tips and objectives, answers to text problems, and test questions. The student site includes chapter review questions and Web-based exercises and will be updated periodically with bulletins on topical environmental issues.

Acknowledgments

The preparation of a text covering such an extensive area, in addition to the supporting materials, is a vast enterprise, and our indebtedness to all those who have contributed to the effort is accordingly great. Colleagues at the Global Development and Environment Institute have supplied essential help and inspiration. Research associate Anne-Marie Codur cowrote the original version of Chapter 18 on global climate change and contributed material to the chapters on population and sustainable development. Especially significant has been the unwavering support of the Institute's codirector, Neva Goodwin, who has long championed the importance of educational materials that bring broader perspectives to the teaching of economics.

Our colleagues Timothy Wise, Frank Ackerman, Kevin Gallagher, Julie Nelson, Liz Stanton, and Elise Garvey provided insights on specific issues. Essential research assistance was given by Josh Uchitelle-Pierce, Adrian Williamson, Baoguang Zhai, Maliheh Birjandi Feriz, Lauren Jayson, Reid Spagna, and Mitchell Stallman, in addition to work by Dina Dubson and Alicia Harvey for the previous edition. Lauren Denizard and Erin Coutts offered administrative support.

The book has greatly benefited from the comments of reviewers including Kris Feder, Richard Horan, Gary Lynne, Helen Mercer, Gerda Kits, Gina Shamshak, Jinhua Zhao, John Sorrentino, Richard England, Maximilian Auffhammer, and Guillermo Donoso and reflects much that we have learned from the work of colleagues at Tufts University and elsewhere, especially William Moomaw, William Wade, Sheldon Krimsky, Molly Anderson, Ann Helwege, Kent Portney, Kelly Gallagher, Paul Kirshen, and Richard Wetzler. Others whose work has provided special inspiration for this text include Herman Daly, Richard Norgaard, Richard Howarth, Robert Costanza, Faye Duchin, Glenn-Marie Lange, John Proops, and many other members of the International Society for Ecological Economics. Fred Curtis, Rafael Reuveny, Ernest Diedrich, Lisi Krall, Richard Culas, and

many other faculty members at colleges in the United States and worldwide have provided valuable feedback from class use. Our editor at M.E. Sharpe, George Lobell, provided support and advice throughout, and Stacey Victor guided us through the production process. Finally we thank the many students we have had the privilege to teach over the years—you continually inspire us and provide hope for a better future.

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Environmental and Natural Resource Economics

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PART ONE
INTRODUCTION

THE ECONOMY AND THE ENVIRONMENT

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CHAPTER 1

Changing Perspectives on the Environment

CHAPTER 1 FOCUS QUESTIONS

- What major environmental issues do we face in the twenty-first century?
- How can economics help us understand these issues?
- How do economic and ecological perspectives differ, and how can we combine them to address environmental issues?

1.1 ECONOMICS AND THE ENVIRONMENT

Over the past four decades, we have become increasingly aware of environmental problems facing communities, countries, and the world. During this period, natural resource and environmental issues have grown in scope and urgency. In 1970, the Environmental Protection Agency was created in the United States to respond to what was at that time a relatively new public concern with air and water pollution. In 1972, the first international conference on the environment, the United Nations Conference on the Human Environment, met in Stockholm. Since then, growing worldwide attention has been devoted to environmental issues.

In 1992 the United Nations Conference on Environment and Development (UNCED) met in Rio de Janeiro, Brazil, to focus on major global issues, including depletion of the earth's protective ozone layer, destruction of tropical and old-growth forests and wetlands, species extinction, and the steady buildup of carbon dioxide and other "greenhouse" gases causing global warming and climate change. Twenty years later, at the United Nations Rio + 20 Conference on Sustainable Development, countries of the world "reaffirmed commitments" to integrating environment and development but acknowledged limited progress toward these goals.[1] In 2012, the United Nations Environmental Programme (UNEP) report *Global Environmental Outlook 5* found that "burgeoning populations and growing economies are pushing ecosystems to destabilizing limits." According to the report:

> The twentieth century was characterized by exceptional growth both in the human population and in the size of the global economy, with the population quadrupling to 7 billion [in 2011] and global economic output increasing more than 20-fold. This expansion has

> been accompanied by fundamental changes in the scale, intensity, and character of society's relationship with the natural world. Drivers of environmental change are growing, evolving, and combining at such an accelerating pace, at such a large scale and with such widespread reach that they are exerting unprecedented pressure on the environment.[2]

With the exception of ozone depletion, an area in which major reductions in emissions have been achieved by international agreement, the UNEP report offers evidence that the global environmental problems identified at UNCED in 1992 in the areas of atmosphere, land, water, biodiversity, chemicals, and wastes have continued or worsened. UNEP Global Environmental Outlook reports have identified nitrogen pollution in freshwater and oceans, exposure to toxic chemicals and hazardous wastes, forest and freshwater ecosystem damage, water contamination and declining groundwater supplies, urban air pollution and wastes, and overexploitation of major ocean fisheries as major global issues. Underlying all these problems is global population growth, which adds more than 70 million people a year. World population, which exceeded 7 billion in 2011, is expected to grow to around 9 billion by 2050.

Scientists, policy makers, and the general public have begun to grapple with questions such as: What will the future look like? Can we respond to these multiple threats adequately and in time to prevent irreversible damage to the planetary systems that support life? One of the most important components of the problem, which rarely receives sufficient attention, is an economic analysis of environmental issues.

Some may argue that environmental issues transcend economics and should be judged in different terms from the money values used in economic analysis. Indeed, this assertion holds some truth. We find, however, that environmental protection policies are often measured—and sometimes rejected—in terms of their economic costs. For example, it is extremely difficult to preserve open land that has high commercial development value. Either large sums must be raised to purchase the land, or strong political opposition to "locking up" land must be overcome. Environmental protection organizations face a continuing battle with ever-increasing economic development pressures.

Often public policy issues are framed in terms of a conflict between development and the environment. An example is the recent debate over "fracking," or hydraulic fracturing to obtain natural gas. Producing natural gas can be profitable and increase the nation's energy supplies, but there are social and environmental costs to communities. Similarly, opponents of international agreements to reduce carbon dioxide emissions argue that the economic costs of such measures are too high. Supporters of increased oil production clash with advocates of protecting the Arctic National Wildlife Refuge. In developing countries, the tension between the urgency of human needs and environmental protection can be even greater.

Does economic development necessarily have a high environmental price? Although all economic development must affect the environment to some degree, is "environment-friendly" development possible? If we must make a tradeoff between development and environment, how should the proper balance be reached? Questions such as these highlight the importance of environmental economics.

Two Approaches

In this book we explore two approaches to addressing natural resource and environmental economics. The first, or traditional, approach uses a set of models and

techniques rooted in the standard neoclassical mainstream of economic thought to apply economic concepts to the environment.[a] The second approach, known as **ecological economics**, takes a different perspective.[3] Rather than applying economic concepts *to* the environment, ecological economics seeks to place economic activity *in the context of* the biological and physical systems that support life, including all human activities.

ecological economics
an economic perspective that views the economic system as a subset of the broader ecosystem and subject to biophysical laws.

nonrenewable resources
resources that are available in a fixed supply, such as metal ores and oil.

renewable resources
a resource that is supplied on a continuing basis by ecosystems; renewable resources such as forests and fisheries can be depleted through exploitation.

common property resources
a resource that is not subject to private ownership and is available to all, such as the oceans or atmosphere.

public goods
goods that are available to all (nonexclusive) and whose use by one person does not reduce their availability to others (nonrival).

externalities
an effect of a market transaction that changes the utility, positively or negatively, of those outside the transaction.

third-party effects
effects of market transactions that affect people other than those involved in the transaction, such as industrial pollution that affects a local community.

solar energy
the energy supplied continually by the sun, including direct solar energy as well as indirect forms such as wind energy and flowing water.

The Traditional Economic Perspective

Several models in economic theory specifically address environmental issues. One important application of neoclassical economic theory deals with the allocation of **nonrenewable resources** over time. This analysis is important in understanding such issues as the depletion of oil and mineral resources and also has applications to **renewable resources** such as agricultural soils. Other economic analyses deal with **common property resources** such as the atmosphere and oceans and **public goods** such as national parks and wildlife preserves. Because these resources are not privately owned, the economic principles governing their use are different from those affecting goods traded in the market.

Another central concept in neoclassical economic analysis of the environment is that of **externalities**, or **external costs and benefits**. The theory of externalities provides an economic framework for analyzing the costs of environmental damage caused by economic activities or the social benefits created by economic activity that improves the environment. Externalities are also sometimes referred to as **third-party effects**, because a market transaction that involves two parties—for example, someone buying gasoline from a filling station—also affects other people, such as those exposed to pollution from producing and burning the gasoline.

Modern environmental economic theory, built on this foundation, addresses many issues, ranging from overfishing to fossil-fuel depletion to parkland conservation.[4] In this text, we investigate how these economic concepts can help frame environmental questions and provide guidance for environmental policy making.

The Ecological Economics Perspective

Ecological economics takes a broader perspective in framing environmental questions by incorporating laws derived from the natural sciences. For example, to understand the collapse of many important ocean fisheries, ecological economics refers to population biology and ecology as well as to the economic view of fish as a resource for production.

Ecological economics theorists emphasize the importance of energy resources, especially fossil fuels, in current economic systems. All ecological systems depend on energy inputs, but natural systems rely almost entirely on **solar energy**. The rapid growth of economic production during the twentieth century required enormous energy inputs, and global economic systems are making even greater energy demands in the twenty-first century. The availability and environmental implications of energy use are central issues for ecological economics.

[a] Neoclassical price theory, based on the concepts of marginal utility and marginal productivity, emphasizes the essential function of market price in achieving equilibrium between supply and demand.

carrying capacity
the level of population and consumption that can be sustained by the available natural resource base.

A fundamental principle of ecological economics is that human economic activity must be limited by the environment's **carrying capacity**. Carrying capacity is defined as the population level and consumption activities that the available natural resource base can sustain without depletion. For example, when a herd of grazing animals exceeds a certain size, rangeland overgrazing will diminish the potential food supply, leading inevitably to a population decline.

For the human population, the issue is more complex. The issue of food supplies is certainly relevant as the world population, which surpassed 7 billion in 2012, grows to a projected 9 billion in 2050. But ecological economists also point to energy supplies, scarce natural resources, and cumulative environmental damage as constraints to economic growth. They argue that the standard theory gives these factors insufficient weight and that major structural changes in the nature of economic activity are required to adapt to environmental limits.

In this text, we consider insights from both the standard and the ecological versions of environmental economics.[5] Sometimes the theories show significant agreement or overlap, and sometimes there are widely differing implications. The best way to judge which approaches are most fruitful is to apply them to specific environmental issues, as we do throughout this book. First, however, we must understand the relationship between the economic system, natural resources, and the environment.

1.2 A Framework for Environmental Analysis

circular flow
a diagram that indicates the ways resources, such as goods, money, waste, and energy, move through an economy or ecosystem.

How can we best conceptualize the relationship between economic activities and the environment? One way is to start with the traditional **circular flow** diagram used in most economics courses to depict the economic process.

The Circular Flow Model

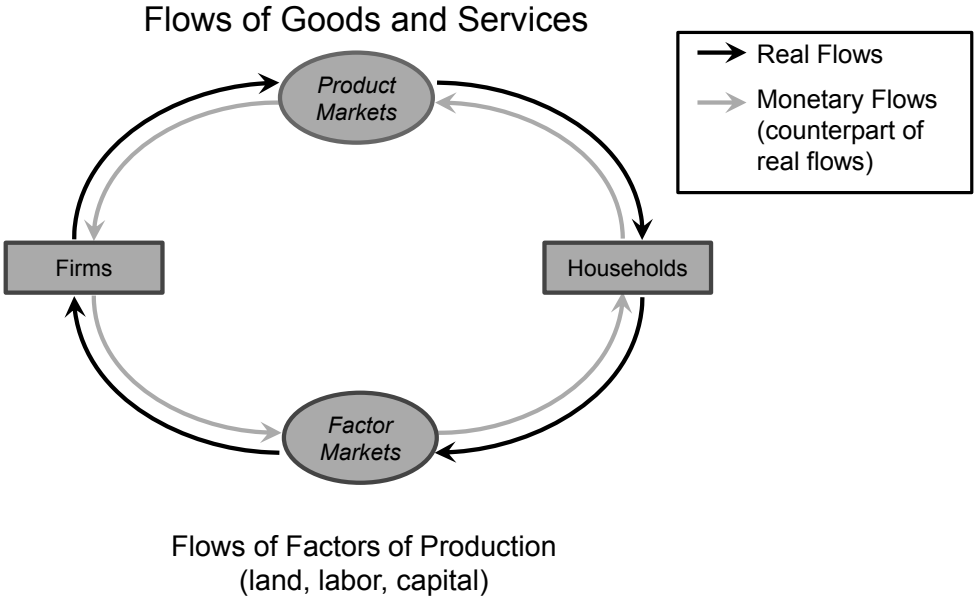
Figure 1.1 shows a simplified model of relationships between households and business firms in two markets: the market for goods and services and the market for factors of production. Factors of production are generally defined as land, labor, and capital. The services that these factors provide are "inputs" to the production of goods and services, which in turn provide the basis for households' consumption needs. Goods, services, and factors flow clockwise; their economic values are reflected in the flows of money used to pay for them, moving counterclockwise. In both markets, the interaction of supply and demand determines a market-clearing price and establishes an equilibrium level of output.

natural resources
resources that occur in a natural state and are valuable for economic activities, such as minerals, timber, and soils.

Where do natural resources and the environment fit in this diagram? **Natural resources**, including minerals, water, fossil fuels, forests, fisheries, and farmland, generally fall under the inclusive category of "land." The two other major factors of production, labor and capital, continually regenerate through the economic circular flow process, but by what processes do natural resources regenerate for future economic use? To answer this question, we need to consider a larger "circular flow" that takes into account ecosystem processes as well as economic activity (Figure 1.2).

Taking this broader view, we notice that the standard circular flow diagram also omits the effects of wastes and pollution generated in the production process. These wastes from both firms and households must flow back into the ecosystem somewhere, either through land disposal or as air and water pollution.

Figure 1.1 **The Standard Circular Flow Model**



In addition to the simple processes of extracting resources from the ecosystem and returning wastes to it, economic activities also affect broader natural systems in subtler and more pervasive ways. For example, modern intensive agriculture changes the composition and ecology of soil and water systems, as well as affecting nitrogen and carbon cycles in the environment.

Figure 1.2, although still quite simple, provides a broader framework for placing the economic system in its ecological context. As you can see, the ecological system has its own circular flow, determined by physical and biological rather than economic laws. This broader flow has only one net "input"—solar energy—and only one net "output"—waste heat. Everything else must somehow be recycled or contained within the planetary ecosystem.

Points of Contact Between Economic and Ecological Flows

source function
the ability of the environment to make services and raw materials available for human use.

resource depletion
a decline in the stock of a renewable resource due to human exploitation.

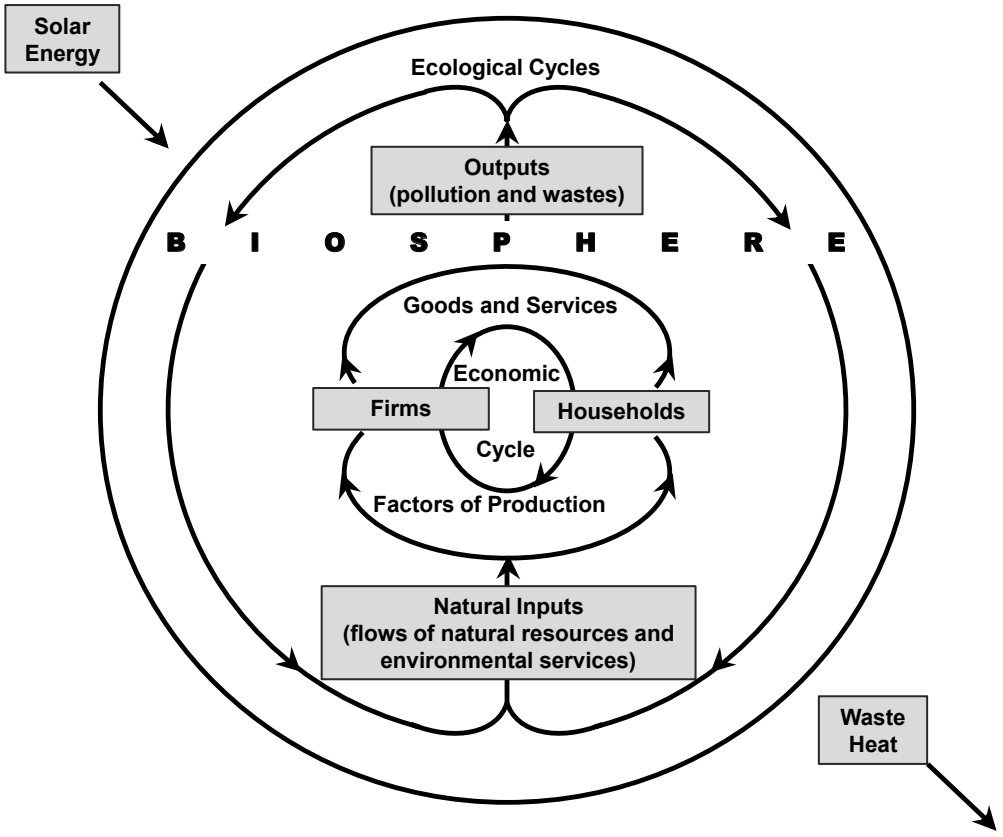
pollution
contamination of soil, water or atmosphere by discharge of harmful substances.

sink function
the ability of natural environments to absorb wastes and pollution.

Understanding the relationships between economic systems, natural resources, and the environment begins with defining the different functions that natural systems serve.

- The environment's **source function** is its ability to make services and raw materials available for human use. Degradation of the source function can occur for two reasons: (1) **Resource depletion**: the resource declines in quantity because humans have drawn on it more rapidly than it could be regenerated; and (2) **Pollution**: contamination of the resource reduces its quality and usefulness.
- The environment's **sink function** is its ability to absorb and render harmless the waste by-products of human activity. The sink function is overtaxed when waste volume is too great within a given time period or when wastes are too toxic. When that happens, aspects of the environment on which we depend (most often soil, water, and atmosphere) become damaged, polluted, or poisoned.

Figure 1.2 **A Broader Circular Flow Model**



These relationships between human activity and the environment define the points of contact between the inner circle of economic flows and the outer circle of ecological flows. Natural resource and environmental economics analyzes the relationships between the two circular flows: the economic system and the ecosystem.

The Economic Valuation Approach

economic valuation
the valuation of a resource in monetary terms.

The traditional economic approach to analysis of natural resource and waste flows uses the same kind of **economic valuation** applied to factors of production, goods, and services. This analysis seeks to put a price on each natural resource and environmental input to the economy, including estimating a price for inputs not usually included in market transactions, such as clean air and water. Economic techniques can be used to assess the money value of damages caused by pollution and waste disposal.

By placing a money value on natural resources and environmental functions, we can include them in the inner, or economic, circular flow. This is the goal of much standard resource and environmental analysis. As we will see, a variety of methods can serve this end, including redefining or reassigning property rights, creating new institutions such as markets for pollution permits, or implicit valuation through surveys and other techniques. If we can be satisfied that these pricing mechanisms accurately reflect the "true value" of resources and of environmental

damages, we can include these factors in a market-oriented economic analysis relatively easily.

The Ecological Systems Approach

The ecological economics approach views the economic system as a subset of the broader ecosystem. In this perspective, an economic valuation expressed in prices can only imperfectly capture the complexity of ecological processes and will sometimes result in serious conflict with ecosystem requirements.

Ecological economists have often argued that standard economic pricing and valuation techniques must either be altered to reflect ecosystem realities or be supplemented by other forms of analysis focusing on energy flows, the carrying capacity of the environment, and the requirements of ecological balance. As we will see in our discussion of analytical techniques and of specific issues in population, energy, resources, and pollution, the standard and ecological economics perspectives have similar practical implications in some cases, but in other cases the two approaches can lead to significantly different conclusions about appropriate resource and environmental policies.

For example, in dealing with the problem of global climate change (discussed at length in Chapter 18), a standard economic approach involves balancing the costs and benefits of avoiding future climate change. Damages caused by rising sea levels or stronger heat waves are estimated in economic terms and then compared to the costs involved in lessening climate change through reducing fossil-fuel use and other measures. Policy recommendations are then formulated to maximize net economic benefits. An ecological economics approach, by contrast, looks first at the physical requirements for a stable climate, in particular the limitation of carbon dioxide and other heat-trapping gases in the atmosphere. After the physical requirements for a stable climate are determined, the economic measures necessary to achieve this are analyzed.

Application of a standard economic approach to the problem of global climate change often results in a recommendation for more limited policy action, to avoid excessive economic costs. The ecological approach usually suggests more drastic action to preserve atmospheric balance. Cost minimization is also a concern for ecological economists, but only after the basic biophysical requirements for ecosystem stability have been met.

1.3 Environmental Microeconomics and Macroeconomics

environmental macroeconomics
an analysis approach that places the human economic system within an ecological context to balance the scale of the economic system within ecological constraints.

Another way of viewing the difference between standard and ecological approaches is in terms of a tension between microeconomic and macroeconomic perspectives on the environment. Standard environmental economic analysis relies largely on microeconomic theory, which focuses on individual resource and environmental issues. **Environmental macroeconomics**, however, can help place the economic system in its broader ecological context. The macroeconomic view gives insight into the interrelationship of economic growth and ecosystems.

Microeconomic and Valuation Techniques

To the extent that we can succeed in putting a price on natural resources and the environment, extensions of standard microeconomic theory can help explain the process