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Environmental & Natural Resource Economics

TENTH EDITION

Tom Tietenberg • Lynne Lewis

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Environmental & Natural Resource Economics

10th Edition

Global Edition

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Preface

A glance at any newspaper will confirm that environmental economics is now a major player in environmental policy. Concepts such as cap-and-trade, renewable portfolio standards, block pricing, renewable energy credits, development impact fees, conservation easements, carbon trading, the commons, congestion pricing, corporate average fuel economy standards, pay-as-you-throw, debt-for-nature swaps, extended producer responsibility, sprawl, leapfrogging, pollution havens, strategic petroleum reserves, payments for ecosystem services, and sustainable development have moved from the textbook to the legislative hearing room. As the large number of current examples in *Environmental & Natural Resource Economics* demonstrates, not only are ideas that were once restricted to academic discussions now part of the policy mix, but they are making a significant difference as well.

New to This Edition

New Features

- New chapter on ecosystem services that covers the state of ecosystem services, valuing ecosystem services, and policy mechanisms to protect and maintain ecosystem services (Chapter 13)
- Updated data on water pricing (Chapter 9), energy (Chapter 7), e-waste (Chapter 8), land use (Chapter 10), forests (Chapter 11), fisheries (Chapter 12), ecosystem services (Chapter 13), air quality (Chapter 15), climate change science (Chapter 16), climate change finance (Chapter 16), carsharing (Chapter 17), and oil spills and water quality trading programs (Chapter 18)
- New Self-Test Exercises (Chapters 13 and 16)
- Many new economic studies discussed
- New and updated tables and figures

New or Expanded Topics

- Dealing with asymmetric information problems (Chapter 2)
- Scale and aggregation issues in benefit-cost analysis (Chapter 3)
- Compensating and equivalent variation approaches to valuation (Chapter 4)

- Combining revealed preference and stated preference approaches to valuation (Chapter 4)
- Benefit transfer and meta-analysis (Chapter 4)
- Innovative responses to valuation challenges (Chapter 4)
- The economics of hydraulic fracturing (fracking) on energy supply (Chapter 7)
- The impact of the Fukushima accident on the role of nuclear power (Chapter 7)
- The relative costs of alternative fuels for electricity generation (Chapter 7)
- Impact of fracking on water demand and local air and water quality (Chapter 7)
- Recycling and fairness issues associated with e-waste (Chapter 8)
- Water markets in Australia (Chapter 9)
- Catch shares and territorial use rights fisheries (Chapter 12)
- Special challenges and innovation in ecosystem valuation (Chapter 13)
- Game theory as a window on climate negotiations (Chapter 16)
- The environmental effectiveness and cost effectiveness of existing carbon pricing programs (Chapter 16)
- The special role of natural gas in climate policy (Chapter 16)
- Carbon pricing design issues: offsets, price volatility, and linking regional systems (Chapter 16)
- Pricing public transport (Chapter 17)
- The effectiveness of tax credits for electric vehicles (Chapter 17)

New Examples and Debates

- Estimating the Benefits of Carbon Emissions Reductions: The Social Cost of Carbon
- Using the Travel Cost Method to Estimate Recreational Value: Beaches in Minorca, Spain
- Valuing the Reliability of Water Supplies: Coping Expenditures in Kathmandu Valley, Nepal
- The Green Paradox
- The Relative Cost-Effectiveness of Renewable Energy Policies in the U.S.
- Energy Efficiency in Rental Housing Markets
- Does Packaging Curbside Recycling with Incentives Promote Efficiency?
- Moving Rivers or Desalting the Sea? Costly Remedies for Water Shortages
- ITQs or TURFs? Species, Space, or Both?
- The Value of Coral Reefs in the U.S. Virgin Islands
- Costa Rica's "Pago por Servicios Ambientales" (PSA) Program
- The Agglomeration Bonus
- The Sulfur Allowance Program after 20 Years
- Three Illustrative Carbon Pricing Programs

- External Benefits of Fuel Economy Standards
- Discounting over Long Time Horizons: Should Discount Rates Decline?
- Willingness to Pay versus Willingness to Accept: Why So Different?
- Distance Decay in Willingness to Pay: When and How Much Does Location Matter?
- What Is the Value of a Polar Bear?
- Does the Advent of Fracking Increase Net Benefits?
- Paying for Ecosystem Services or Extortion?: The Case of Yasuni National Park
- Tradable Quotas for Whales?

An Overview of the Book

Environmental & Natural Resource Economics attempts to bring those who are beginning the study of environmental and natural resource economics close to the frontiers of knowledge. Although the book is designed to be accessible to students who have completed a two-semester introductory course in economics or a one-semester introductory microeconomics course, it has been used successfully in several institutions in lower-level and upper-level undergraduate courses as well as lower-level graduate courses.

The structure and topical coverage of this book facilitates its use in a variety of contexts. For a survey course in environmental and natural resource economics, all chapters are appropriate, although many of us find that the book contains somewhat more material than can be adequately covered in a quarter or even a semester. This surplus material provides flexibility for the instructor to choose those topics that best fit his or her course design. A one-term course in natural resource economics could be based on Chapters 1–13 and 20–21. A brief introduction to environmental economics could be added by including Chapter 14. A single-term course in environmental economics could be structured around Chapters 1–4 and 14–21.

In this tenth edition, we examine many of these newly popular market mechanisms within the context of both theory and practice. Environmental and natural resource economics is a rapidly growing and changing field as many environmental issues become global in nature. In this text, we tackle some of the complex issues that face our globe and explore problems and potential solutions.

This edition retains a strong policy orientation. Although a great deal of theory and empirical evidence is discussed, their inclusion is motivated by the desire to increase understanding of intriguing policy problems, and these aspects are discussed in the context of those problems. This explicit integration of research and policy within each chapter avoids a problem frequently encountered in applied economics textbooks—that is, in such texts the theory developed in earlier chapters is often only loosely connected to the rest of the book.

This is an economics book, but it goes beyond economics. Insights from the natural and physical sciences, literature, political science, and other disciplines are scattered liberally throughout the text. In some cases these references raise outstanding issues that economic analysis can help resolve, while in other cases they affect the structure of the economic analysis or provide a contrasting point of view. They play an important role in overcoming the tendency to accept the material uncritically at a superficial level by highlighting those characteristics that make the economics approach unique.

Intertemporal optimization is introduced using graphical two-period models, and all mathematics, other than simple algebra, is relegated to chapter appendixes. Graphs and numerical examples provide an intuitive understanding of the principles suggested by the math and the reasons for their validity. In the tenth edition, we have retained the strengths that are particularly valued by readers, while expanding the number of applications of economic principles, clarifying some of the more difficult arguments, and updating the material to include the very latest global developments.

Reflecting this new role of environmental economics in policy, a number of journals are now devoted either exclusively or mostly to the topics covered in this book. One journal, *Ecological Economics*, is dedicated to bringing economists and ecologists closer together in a common search for appropriate solutions for environmental challenges. Interested readers can also find advanced work in the field in *Land Economics*, *Journal of Environmental Economics and Management*, *Review of Environmental Economics and Policy*, *Environmental and Resource Economics*, *International Review of Environmental and National Resource Economics*, *Environment and Development Economics*, *Resource and Energy Economics*, and *Natural Resources Journal*, among others.

Two discussion lists that involve material covered by this book are ResEcon and EcolEcon. The former is an academically inclined list focusing on problems related to natural resource management; the latter is a wider-ranging discussion list dealing with sustainable development.

A very useful blog that deals with issues in environmental economics and their relationship to policy is located at http://www.env-econ.net/.

Services on the Internet change so rapidly that some of this information may become obsolete. To keep updated on the various Web options, visit the Companion Website of this text at www.pearsonglobaleditions.com/Tietenberg. The site includes an online reference section with all the references cited in the book. The site also has links to other sites, including the site sponsored by the Association of Environmental and Resource Economists, which has information on graduate programs in the field.

Supplements

For each chapter in the text, the *Online Instructor's Manual*, originally written by Lynne Lewis of Bates College and revised by Nora Underwood of the University of Central Florida, provides an overview, teaching objectives, a chapter outline with key terms, common student difficulties, and suggested classroom exercises. PowerPoint® presentations, prepared by Hui Li of Eastern Illinois University, are available for instructors and include all art and figures from the text as well as lecture notes for each chapter. Professors can download the *Online Instructor's Manual* and the PowerPoint® presentations at the Instructor Resource Center (www.pearsonglobaleditions.com/Tietenberg).

The book's Companion Website, www.pearsonglobaleditions.com/Tietenberg, features chapter-by-chapter Web links to additional reading and economic data. The site also contains Excel-based models that can be used to solve common depletable resource problems numerically. These models, developed by Arthur Caplan and John Gilbert of Utah State University, may be presented in lecture to accentuate the intuition provided in the text, or they may underlie specific questions on a homework assignment.

The Companion Website also provides self-study quizzes for each chapter. Written and updated by Elizabeth Wheaton of Southern Methodist University, each of these chapter quizzes contains 10 multiple-choice questions for students to test what they have learned.

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Lynne Lewis

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1 Visions of the Future

From the arch of the bridge to which his guide has carried him, Dante now sees the Diviners . . . coming slowly along the bottom of the fourth Chasm. By help of their incantations and evil agents, they had endeavored to pry into the future which belongs to the almighty alone, and now their faces are painfully twisted the contrary way; and being unable to look before them, they are forced to walk backwards.

—Dante Alighieri, *Divine Comedy: The Inferno*, translated by Carlyle (1867)

Introduction

The Self-Extinction Premise

About the time the American colonies won independence, Edward Gibbon completed his monumental *The History of the Decline and Fall of the Roman Empire*. In a particularly poignant passage that opens the last chapter of his opus, he re-creates a scene in which the learned Poggius, a friend, and two servants ascend the Capitoline Hill after the fall of Rome. They are awed by the contrast between what Rome once was and what Rome has become:

> *In the time of the poet it was crowned with the golden roofs of a temple; the temple is overthrown, the gold has been pillaged, the wheel of fortune has accomplished her revolution, and the sacred ground is again disfigured with thorns and brambles. . . . The forum of the Roman people, where they assembled to enact their laws and elect their magistrates is now enclosed for the cultivation of potherbs, or thrown open for the reception of swine and buffaloes. The public and private edifices that were founded for eternity lie prostrate, naked, and broken, like the limbs of a mighty giant; and the ruin is the more visible, from the stupendous relics that have survived the injuries of time and fortune. (Vol. 6, pp. 650–651)*

What could cause the demise of such a grand and powerful society? Gibbon weaves a complex thesis to answer this question, suggesting ultimately that the seeds for Rome's destruction were sown by the Empire itself. Although Rome finally succumbed to such external forces as fires and invasions, its vulnerability was based upon internal weakness.

The premise that societies can germinate the seeds of their own destruction has long fascinated scholars. In 1798, Thomas Malthus published his classic *An Essay on the Principle of Population*, in which he foresaw a time when the urge to reproduce would cause population growth to exceed the land's potential to supply sufficient food, resulting in starvation and death. In his view, the most likely response to this crisis would involve rising death rates caused by environmental constraints, rather than a recognition of impending scarcity followed either by innovation or self-restraint.

Generally, our society seems remarkably robust, having survived wars and shortages, while dramatically increasing living standards and life expectancy. Yet, actual historical examples suggest that Malthus's self-extinction vision may sometimes have merit. Example 1.1 examines two specific cases: the Mayan civilization and Easter Island.

EXAMPLE 1.1

A Tale of Two Cultures

The Mayan civilization, a vibrant and highly cultured society that occupied parts of Central America, did not survive. One of the major settlements, Copán, has been studied in sufficient detail to learn reasons for its collapse.

After A.D. 400 the population growth began to bump into environmental constraints, specifically the agricultural carrying capacity of the land. The growing population depended heavily on a single, locally grown crop—maize—for food. By early in the sixth century, however, the carrying capacity of the most productive local lands was exceeded, and farmers began to depend upon more fragile parts of the ecosystem. Newly acquired climate data show that a 2-century period with a favorable climate was followed by a general drying trend lasting four centuries that led to a series of major droughts. Food production failed to keep pace with the increasing population.

By the eighth and ninth centuries, the evidence reveals not only high levels of infant and adolescent mortality but also widespread malnutrition. The royal dynasty, an important source of leadership, collapsed rather abruptly sometime about A.D. 820–822.

The second case study, Easter Island, shares some remarkable similarities with both the Mayan case and the Malthusian vision. Easter Island lies some 2000 miles off the coast of Chile. Current visitors note that it is distinguished by two features: (1) its enormous statues carved from volcanic rock and (2) a surprisingly sparse vegetation, given the island's favorable climate and conditions. Both the existence of these imposing statues and the fact that they were erected at a considerable distance from the quarry suggests the presence of an advanced civilization, but current observers see no sign of it. What happened? According to scholars, the short answer is that a rising population, coupled with a heavy reliance on wood for housing, canoe building, and statue transportation, decimated the forest (Brander and Taylor, 1998). The loss of the forest contributed to soil erosion, declining soil productivity, and, ultimately, diminished food production. How did the community react to the impending scarcity? Apparently, the social response was war among the remaining island factions and ultimately, cannibalism.

We would like to believe not only that in the face of impending scarcity, societies would react by changing behavior to adapt to the diminishing resource supplies, but also that this benign response would follow automatically from a recognition of the problem. We even have a cliché to capture this sentiment: "necessity is the mother of invention." These stories do point out, however, that nothing is automatic about a problem-solving response. Sometimes societies not only fail to solve the problem but their reactions can actually intensify it.

Sources: Webster, D., Freter, A., & Golin, N. Copan: The rise and fall of an ancient maya kingdom. (2000). Fort Worth: Harcourt Brace Publishers; Brander, J. A., & Taylor, M. S. (1998). The simple economics of Easter Island: A Ricardo-Malthus model of renewable resource use. *The American Economic Review*, *88*(1), 119–138; Turner, B. L., & Sabloff, J. A. (2012). Classic period collapse of the central Maya lowlands: Insights about human–environment relationships for sustainability. *Proceedings of the National Academy of Sciences*, *109*(35), 13908–13914; Pringle, Heather. (9 November 2012). Climate change had political, human impact on ancient Maya. *Science*, 730–731.

Future Environmental Challenges

Future societies will also be confronted by resource scarcity as well as with accumulating pollutants. Many specific examples of these broad categories of problems are discussed in detail in the following chapters. This section provides a flavor of what is to come by illustrating the challenges posed by one pollution problem (climate change) and one resource scarcity problem (water accessibility).

Climate Change

Energy from the sun drives the earth's weather and climate. Incoming rays heat the earth's surface, radiating energy back into space. Atmospheric "greenhouse" gases (water vapor, carbon dioxide, and other gases) trap some of the outgoing energy.

Without this natural "greenhouse effect," temperatures on the earth would be much lower than they are now and life as we know it would be impossible. It is possible, however, to have too much of a good thing. Problems arise when the concentration of greenhouse gases increases beyond normal levels, thus retaining excessive heat somewhat like a car with its windows closed in the summer.

Since the Industrial Revolution, greenhouse gas emissions have increased, considerably enhancing the heat-trapping capability of the earth's atmosphere. According to the Intergovernmental Panel on Climate Change National Research Council, 2010, "Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia." It also noted that based upon multiple lines of evidence "Human influence on the climate system is clear."

As the earth warms, the consequences are expected to affect both humans and ecosystems. Some damage to humans is caused directly by increased heat, as shown by the heat waves that resulted in thousands of deaths in Europe in the summer of 2003. Human health can also be affected by pollutants, such as smog, that are exacerbated by warmer temperatures. Rising sea levels (as warmer water expands and previously frozen glaciers melt), coupled with an increase in storm intensity, are expected to flood coastal communities with greater frequency. Ecosystems will be subjected to unaccustomed temperatures; some will adapt by migrating to new areas, but many others are not expected to be able to adapt in time. While these processes have already begun, they will intensify slowly throughout the century.

Climate change also has an important moral dimension. Due to their more limited adaptation capabilities, many developing countries, which have produced relatively small amounts of greenhouse gases, are expected to be the hardest hit as the climate changes.

Dealing with climate change will require a coordinated international response. That is a significant challenge to a world system where the nation-state reigns supreme and international organizations are relatively weak.

Water Accessibility

Another related class of threats is posed by the interaction of a rising demand for resources in the face of a finite supply. Water provides a particularly interesting example because it is so vital to life.

According to the United Nations, about 40 percent of the world's population lives in areas with moderate-to-high water stress. ("Moderate stress" is defined in the U.N. Assessment of Freshwater Resources as "human consumption of more than 20 percent of all accessible renewable freshwater resources," whereas "severe stress" denotes consumption greater than 40 percent.) By 2025, it is estimated that about two-thirds of the world's population—about 5.5 billion people—will live in areas facing either moderate or severe water stress.

This stress is not uniformly distributed around the globe. For example, in parts of the United States, Mexico, China, and India, groundwater is already being consumed faster than it is being replenished, and aquifer levels are steadily falling. Some rivers, such as the Colorado in the western United States and the Yellow in China, often run dry before they reach the sea. Formerly enormous bodies of water, such as the Aral Sea and Lake Chad, are now a fraction of their once-historic sizes. Glaciers that feed many Asian rivers are shrinking.

According to U.N. data, the continents most burdened by a lack of access to sufficient clean water are Africa and Asia. Up to 50 percent of Africa's urban residents and 75 percent of Asians are estimated to lack adequate access to a safe water supply.

The availability of potable water is further limited by human activities that contaminate the remaining supplies. According to the United Nations, 90 percent of sewage and 70 percent of industrial wastes in developing countries are discharged without treatment. And climate change is expected to intensify both the frequency and duration of droughts, simultaneously increasing the demand for water and reducing its supply.

Some arid areas have compensated for their lack of water by importing it via aqueducts from more richly endowed regions or by building large reservoirs, but this solution can promote conflict when the water transfer or the relocation of people living in the area to be flooded by the reservoir is resisted. Additionally, aqueducts and dams may be geologically vulnerable. For example, in California,