ECONOMICS OF ENVIRONMENTAL REGULATION

William A. Brock
University of Wisconsin, USA

Keywords: economics, environmental regulation, lake management, uncertainty, values, political consideration, regulatory costs

Contents

1. Introduction
2. A Lake Management Problem
3. Uncertainty, Values, Political Considerations, Regulatory Costs
4.Conclusions
Glossary
Bibliography
Biographical Sketch

Summary

This entry develops some economics of the management of ecosystems where the ecosystem's dynamics are nonlinear, where there is a hierarchy of temporal and spatial scales of activity, and where multiple basins of attraction can be present. These features, for which there is increasing scientific evidence, generate difficulties for management agencies because data and other sources of evidence seldom allow confidence that one has specified the right model, but the policy consequences of wrongly specifying a single steady state model in a world of multiple steady states can be serious.

1. Introduction

This entry gives a brief explanation to some recent literature in the economics of environmental management and regulation, where modeling of the ecological side is more detailed than usual, and where stress is placed upon the hierarchy of temporal and spatial scales that appear to be present in actual ecosystems. Here "management" and "regulation" will be taken as analytical synonyms. Similar analytical structures are useful in both management and regulation. However, the regulatory area focuses more on issues such as relative efficiency of different modes of implementation of desired goals. For example, the regulatory area stresses issues such as comparison of decentralized and market based modes of implementation, in contrast with centralized and command/control modes of implementation.

The economics of environmental regulation may be viewed at several levels. At the highest and most abstract level, the question is how the peoples of Earth want to organize activity at the macro-scale of planet Earth to maximize the level of well being of human beings and their descendants (including all future generations). Indeed, at this abstract level, the concern includes the well being of other organisms such as the great apes, the chimpanzees, and other "charismatic" species, but probably not the direct well being of "nuisance" species like malarial mosquitoes. It is currently a great debate where the web of caring ends across species, but the web of caring surely includes human beings and that posture is taken here.

At a more specific and concise level of abstraction, the goal might be to manage human activities in order to maximize the well being of the current population of human beings and their descendants (including all future generations). Since human welfare is coupled to the environment, one must face the issue of managing coupled economic/ecosystems to achieve goals. The area of science that this entry attempts to exposit is vast. Therefore, the exposition is specialized to the very narrow area of the economics of regulation of dynamic ecosystems whose dynamics may display multiple basins of attraction.

There will also be emphasis on complications and considerations due to a hierarchy of time scales of ecosystem activity, where there is a rough order of magnitude in difference in speed across each time scale clump of activity. This issue is raised here because it turns out that evidence is suggestive of "clumping" structure of temporal speeds of ecosystem activity, with each "clump" roughly separated from the next by an order of magnitude difference in speed. Furthermore, similar "clumping" is observed in spatial domains of ecosystem activity, with the temporal speed and the spatial size being positively correlated. This kind of evidence is summarized in ecosystem studies in various ways. A popular method of presentation is a Stommel diagram. This diagram represents the results of a type of spatial/temporal spectral analysis where height of spectral power, or some other measure of frequency of activity at a particular location, on the floor of the diagram is represented by iso-spectral height lines. The axes represent the logarithms of time duration and spatial size. References are given in the annotated bibliography.

It will turn out that much recent research in ecology suggests that the specialization taken here is not so narrow after all. It is necessary to clarify a point on the use of language before beginning. This entry uses the language of "optimization" for expository purposes. It is important to always keep in mind that environmental problems usually do not submit to simple maximization of some numerical objective function. At the minimum, the heterogeneity of interests would demand something like a vector-valued criterion, not a numerical one. In some important cases, there is no compensatory tradeoff between material goods and deeply held spiritual or environmental values.

Consider a dramatic example of a native tribe in Amazonia facing a multinational wishing to desecrate their sacred rainforest by oil drilling. The tribe will commit suicide if the rainforest is invaded by such a commercial interest. The multinational offers to make each one of them a millionaire in compensation, yet each tribal member decides to commit suicide anyway. Examples almost as dramatic as this one come up all the time in environmental issues, and the environmental policy economists who ignore these kinds of issues do so at their peril. In cases like this, where there are no substitution possibilities available to design a compensatory mechanism, and there is no technology available with which one can drill without desecrating the rainforest from the tribe's point of view, any sensible and moral criterion of "optimization" would probably demand that the tribe's rainforest be left alone.

To put it another way, in benefit/cost language, the "willingness-to-accept" (WTA) for drilling rights for this tribe is plus infinity. Morality, ethics, and the material poverty of the tribe (even though it may be spiritually rich) demand use of a WTA criterion rather than a willingness-to-pay criterion in making the decision of whether to drill the rainforest. Hence, in this case, since the true WTA of the tribe is plus infinity (we assume that there is no strategic "posturing" by the tribe in this hypothetical example), and since the WTA of non-drilling of the rest of the world is finite, WTA-based benefit/cost analysis delivers the decision: do not drill. In view of this and other difficult ethical and moral issues involved in the interaction between environmental regulation and the distribution of incomes, optimization of some numerical criterion is not likely to be appropriate. Nevertheless, this entry will use the language of optimization for expository purposes, even though the general theme of the entry is regulation in the "overall public interest," and even though that criterion is difficult to define.

To put it another way, one could imagine that society as a whole sets a vector of goals such as some concept of efficiency, ethics, fairness, and sustainability. In this view, the economist's job is to design best ways of achieving the targets set by society. This problem could potentially be framed as a conditional type of optimization problem. Hence, this entry will continue to use the language of "optimization" in the exposition that follows. Concepts such as "utility" will be interpreted more broadly than usual in order to encompass notions of "conditional optimality," where the problem is to find the most effective way to reach a goal set by other mechanisms such as democratic political choice rather than economic valuation analysis.

This entry develops the economics of environmental regulation for a coupled economic and ecological system, where ecological dynamics seriously incorporates an ecological scientific knowledge base requiring the special expertise of a natural science such as limnology. The example of management of a lake and its watershed is used as an expository example. The emphasis will be on problems raised by non-convexities in the underlying dynamics in this kind of ecological management problem. Discussion will be intuitive and heuristic. References are given in the annotated bibliography for details.

The lake example will be used as a contextual framework to give a general discussion of problems faced by the economics of regulation of realistic ecosystems at all levels, ranging from the micro-level of a small lake to the meso-level of large lakes and landscape systems, to the macro-level of world carbon, nitrogen cycles, and global climate change. The discussion includes practical issues such as the use of regulatory tiering, copayment schemes, and other regulation modes besides the standard "market-based" schemes such as user charges, tradeable permits, and "Pigouvian" taxes.

-
-
-

Bibliography

Becker R. and Boyd J. (1997). *Capital Theory, Equilibrium Analysis and Recursive Utility*. 350 pp. Oxford: Blackwell. [A basic reference on mathematical models in general capital theory, which includes many environmental management problems when the variables are reinterpreted appropriately.]

Brock W. (1977). A polluted golden age. In V. Smith, ed. *Economics of Natural and Environmental Resources*. pp 441-461. New York: Gordon and Breach. [The deterministic model treated in the text is a generalization of the model in this paper, to include a positive feedback mechanism.]

Brock W. and Evans D. (1986). *The Economics of Small Business: Their Role and Regulation in the US Economy*. 215 pp. New York: Holmes and Meier. [This book reviews not only empirics and theory about smaller businesses in the US, but also the theory and practice of regulating environmental problems caused by smaller businesses. A discussion is given of instances where the political system acts rather like an optimally designed efficiency-based system of regulatory tiering and when it does not so act.]

Brock W., Maler K., and Perrings C. (2000). Resilience and sustainability: the economic analysis of non-linear dynamic systems. In C. Holling, L. Gunderson, and G. Peterson, eds. *Theories for Sustainable Futures*, (forthcoming). [This paper shows how the first and second welfare theorems of classical economics are modified when an ecosystem with alternative stable states is coupled onto the traditional general equilibrium framework. It locates sufficient conditions to show that, if the economic component satisfies classical assumptions, decentralized instruments can implement a desired path of use of the ecosystem component, even though the ecosystem dynamics themselves are not “classical.”]

Carpenter S. (2000). Alternate states of ecosystems: evidence and its implications for environmental decisions. In M. Press, N. Huntley, and S. Levin, eds. *Ecology: Achievement and Challenge*. London: Blackwell. [This paper contains a strong argument that recent theories in the natural sciences, as well as recent evidence, suggest that dynamic ecosystems with multiple basins of attraction may be ubiquitous at scales ranging from small shallow lakes and farm ponds to the global climate system as a whole. This paper and its multitude of references to theories and evidence serves as a foundation of an argument that the economics of regulation of ecosystems with dynamics that may have multiple basins of attraction is of first order importance, especially in the real world where scientific uncertainty looms large.]

Carpenter S. and Kitchell J., eds. (1993). *The Trophic Cascade in Lake*. 385 pp. Cambridge: Cambridge University Press. [A basic limnology reference that gives a detailed discussion of food chains in lakes, as well as basic principles of limnology.]

Chichilnisky C. (1996). An axiomatic approach to sustainable development. *Social Choice and Welfare* **13**, 231–257. [An article that formulates a useful welfare criterion that attempts to avoid over-weighting the present.]

Clark W. (1985). Scales of climate impacts. *Climatic Change* **7**, 5–27. [This article discusses hierarchies of characteristic temporal and spatial scales at which most of the variations in climates, ecosystems, and societies are observed, as well as summarizing evidence in the form of cluster diagrams and Stommel diagrams.]

Dasgupta P. and Heal G. (1979). *Economic Theory and Exhaustible Resources*. 501 pp. Cambridge: Cambridge University Press. [A basic reference that reviews a good part of the economics of regulation of renewable resources and exhaustible resources.]

Dixit A. and Pindyck R. (1994). *Investment under Uncertainty*. 468 pp. Princeton: Princeton University Press. [This book gives a nice treatment of management in the face of uncertainty and potential irreversibility, which is applicable to environmental management under realistic uncertainties.]

Easley D. and Kiefer N. (1988). Controlling a stochastic process with unknown parameters. *Econometrica* **56**(5), 1045–1064. [An article that could be used as a mathematical metaphor for a form of adaptive management. The article draws connections with the multi-armed bandit literature in statistics and locates sufficient conditions on discount rates and other parameters for complete learning.]

Farber D. (1999). *Eco-Pragmatism: Making Sensible Environmental Decisions in an Uncertain World*. 210 pp. Chicago: University of Chicago Press. [This book argues for a form of dynamical environmental regulation and management where the public, as well as experts, participate in a mutually informative and interactive process (such as a political process where decisions are ultimately made by voting) to establish goals and ends, while specialized experts such as economists find the best way to achieve those goals and ends.]

Folke C., Holling C., and Perrings C. (1996). Biological diversity, ecosystems, and the human scale. *Ecological Applications* **6**(4), 1018–1024. [An article that discusses problems in environmental management caused by complex dynamics and cross-scale interactions.]

Gunderson L., Holling C., and Light S., eds. (1995). *Barriers and Bridges*. 593 pp. New York: Columbia University Press. [A book that documents common patterns across a large set of case studies of ecosystem management. The adaptive cycle diagram is used to illustrate common features of the histories of many case studies.]

Hartley P. (1997). *Conservation Strategies for New Zealand*. 526 pp. Wellington, New Zealand: New Zealand Business Roundtable. [This 500 page book discusses not only how the government conservation departments in Australia and New Zealand can be improved by forcing them to formulate transparent and auditable goals and to redesign career incentives, but also how to design institutional frameworks for conservation policy and environmental regulation policy to unleash creativity in achieving environmental goals comparable to the level of creativity in private business in achieving its goals. The book draws on many of the creative ideas unleashed by the famous New Zealand restructuring, liberalization, and institutional reform period.]

Holling C. (1994). An ecologist's view of the Malthusian conflict. In K. Lindahl-Kiessling, H. Landberg, eds. *Population, Economic Development, and the Environment*. Oxford: Oxford University Press. pp. 79–103. [An article that argues that nature, people, and economies, are no coevolving on larger and larger scales where unobserved slow variable dynamics are creating more "accidents waiting to happen."]

Ludwig D. (1995). A theory of sustainable harvesting. *Siam Journal of Applied Mathematics* **55**(2), 564–575. [An article that studies the impact of adding layers of uncertainty about the dynamics in an optimal harvesting problem. The general finding is that caution increases as more layers of uncertainty are added. The effects of small continuous shocks and large, but rare, shocks is discussed.]

Majumdar M., ed. (1992a). *Decentralization in Infinite Horizon Economies*. 190 pp. Boulder, Colorado: Westview Press. [A book that develops basic theory of decentralization for infinite horizon economic models.]

Majumdar M. (1992b). *Equilibrium and Dynamics*. 361 pp. London: MacMillan Press. [This book contains articles by Majumdar and Peleg, and Mitra that extend value loss methods to nonconvex technologies.]

Marimon R. (1989). Stochastic turnpike property and stationary equilibrium. *Journal of Economic Theory* **47**(2), 282–306. [This paper contains general convergence results for optimal solutions of stochastic, multi-sectoral, infinite horizon optimization problems for the important case where the payoff function is concave and the constraint set is convex. It also surveys the literature in this large area, especially the important "value-loss" area where the discount rate is near zero (or actually is zero where the "overtaking" ordering is used). If the discount rate is near zero or is actually zero, convergence always occurs to a unique stationary measure (that is, a unique stochastic steady state) if modest regularity conditions are imposed. These results, plus the results of Majumdar and Mitra and Easley and Kiefer, hint at the possibility for related results on controlling stochastic processes with unknown parameters.]

McDonald R. and Siegel D. (1986). The value of waiting to invest. *Quarterly Journal of Economics* November, 707–727. [An article that shows how the option value inherent in irreversibility can lead to a strong environmental preservationist posture even in conventional benefit/cost analysis.]

Perrings C. (1997). *Economics of Ecological Resources*. 254 pp. Cheltenham: Edward Elgar. [A collection of papers on the economics of environmental regulation where the ecology is taken seriously by a leading writer in this area.]

Perrings C., Maler K., Folke C., Holling C., and Jansson B. (1995). *Biodiversity Loss*. 332 pp. Cambridge: Cambridge University Press. [A collection of writings on biodiversity and environmental management.]

Pizer W. (1996). *Modeling Long-Term Policy under Uncertainty*. 179 pp. PhD Thesis, Department of Economics, Harvard University. [A thesis that generalizes aggregative approaches to estimation of welfare impacts of potential global warming to include better treatments of uncertainty by using recently developed methods in computational Bayes analysis.]

Samson F. and Knopf F., eds. (1996). *Ecosystem Management: Selected Readings*. 462 pp. New York: Springer. [This book is a collection of basic articles on ecosystem management that covers (a) the understanding of diversity, its measurement, and strategies to preserve it; (b) understanding and restoration of ecological processes; (c) maintenance of biotic integrity; and (d) strategies for promotion of ecological sustainability. This entry draws upon several articles in this book, including Holling, Daily and Ehrlich, Costanza, Wainger, Folke and Maler.]

Sheffer M. (1997). *Ecology of Shallow Lakes*. New York: Chapman and Hall. [A book on shallow lake limnology, which we drew upon heavily in this article.]

Smith V., ed. (1977). *Economics of Natural and Environmental Resources*. 504 pp. New York: Gordon and Breach. [A collection of seminal articles on the economics of environmental regulation.]

Walters C. and Holling C. (1990). Large-scale management experiments and learning by doing. *Ecology* **71**(6), 2060–2068. [An article that discusses the principles of adaptive management from a practical point of view.]

Biographical Sketch

Professor William A. Brock teaches economics at the University of Wisconsin, Madison. He received his Ph.D. degree from the University of California at Berkeley and his AB degree from the University of Missouri, Columbia. His major interests include economic dynamics, econometrics, and complexity theory.