Sustainability, Economics, and Natural Resources

Shashi Kant *Editor*

Post-Faustmann Forest Resource Economics

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Sustainability, Economics, and Natural Resources

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About the Series

An adequate economic theory of sustainability cannot be based on the neoclassical paradigm that is at the root of most sustainability issues. A new economic theory, rather than a new public policy based on the old theory, will be needed to guide humanity toward sustainability. The challenge to economists, with the help of other social scientists, is to build a new dominant economic paradigm based on a more organic, holistic, and integrative approach. The book series Sustainability, Economics, and Natural Resources aims to integrate the concept of sustainability fully into economics and to provide a foundation for that new economic paradigm. The series is designed to reflect the multi- and interdisciplinary nature of the needed paradigm and will cover and integrate concepts from different streams such as agent-based modeling, behavioral economics, chaos theory, complexity theory, ecological economics, evolutionary economics, evolutionary game theory, institutional economics, post-Keynesian consumer theory, social choice theory, S-matrix theory, and quantum theory. The series will be a forum for new ideas and concepts concerning recent developments and unsolved problems in sustainability and the applications of these ideas to the policy scenario. Each volume in the series is selfcontained. Together these volumes provide dramatic evidence of the range of approaches to sustainability issues found in economic thinking.

Dr. Shashi Kant, editor-in-chief of the series, has received the Queen's Award for Forestry (2008), the Scientific Achievement Award of Canadian Institute of Forestry (2007), the Scientific Achievement Award of the IUFRO (2005), and the Ontario's Premier Research Excellence Award (2004) for his research contributions.

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Editor

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Editor
Shashi Kant
Faculty of Forestry
University of Toronto
Toronto, ON
Canada

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Dedicated to Dr. S. P. Singh Yadav
and Sanjay Yadav

Preface and Acknowledgments

The current paradigm of forest economics is based on Faustmann Formulation (FF) of land expectation value proposed by Martin Faustmann, a German forester, in 1849. In fact, it was a great achievement by a forester to propose a formulation that captures some fundamental economic features of capital theory which were not recognized by great economists at that time. However, the followers of the FF approach have trapped themselves into the past, and have not shown any indication of economic acumen of the great Faustmann. This has resulted in a common problem in the current paradigm of forest economics, known as Faustmann Forest Resource Economics (FFRE), to prescribe the application of a single (FF) approach to all situations irrespective of the specific features of the situation under consideration. The current state of forest economics is similar to that of neoclassical economics, and as a result forest economics as well as neoclassical economics are full of inefficiencies. In neoclassical economics, inefficiencies are due to its "locked-in" position in rational economic man, while in forest economics inefficiencies are due to its "locked-in" position in the FF.

During the period of about 163 years, between 1849 and 2012, the economic, social, environmental, and scientific context of forests and forest management has changed by leaps and bounds. Forest management has moved away from sustained yield timber management (SYTM) to sustainable forest management (SFM). The concept of SFM incorporates human preferences for timber and non-timber products, preferences for marketed as well as non-marketed products and services, the preferences of industrial as well as non-industrial agents, including Aboriginal and other local people, and the preferences of future generations as well as the present one. It takes account of diversity of preferences across agents, communities, time, and generations, and incorporates preferences that are revealed through the market as well as through non-market mechanisms. Forests, in the context of SFM, are valuable for their contributions to ecosystem functioning as well as their physical outputs. The role of multiple forest ecosystem services in climate change, human health, environmental sustainability, and human development is being increasingly recognized, and attention is being focused on enhancing the contribution of forests to a "green" economy rather than the traditional contribution of forests to an industrial economy.

During the period of 163 years, there have been many developments in economics. Many new streams of economics, such as agent-based economics, behavioral economics, complexity theory, ecological economics, evolutionary game theory, social choice theory, and public choice theory, have extended the horizons of economic thinking much beyond neoclassical economics. Somehow the forest economics profession has not kept the pace with these new and emerging contextual as well as theoretical realities. There have been some efforts to transform forest economics, but not at the desired scale, and now there is an urgent need to take big and concrete steps in that direction.

This volume is an important, though not the first, step in that direction. In fact, the first step was the article "Extending the Boundaries of Forest Economics" in Volume 5 (2003) of Forest Policy and Economics. The next step was starting of this book series. In the first volume of the book series, leading economists from behavioral economics, complexity theory, resource economics, and social choice theory discussed key aspects of the economics of SFM, including complexity, ethical issues, consumer choice theory, intergenerational equity, non-convexities, and multiple equilibria. The second volume focused on institutions for sustainable forest management and the third volume on justification, characterization, and indicator of sustainability. This is the fourth volume of the series.

The focus of this volume is on the new paradigm of forest economics termed as Post-Faustmann Forest Resource Economics (PFFRE). The first chapter lays the foundation of the PFFRE, and presents the key distinctions between the FFRE and the PFFRE. The volume includes other 12 chapters that address issues related to forest economics from perspectives different than the FFRE. Five of these chapters are focused on issues related to human behavior that is different than the rational economic man or Chicago man, two chapters on public choice theory, two on systems approaches to forest resource economics, and three on incremental approaches to incorporate new features in the FFRE. Some of the chapters included in this volume were presented at the XXIII IUFRO World Congress, 2010, Seoul. The volume is not a mere re-printing of congress papers, however. The original selection of papers and the rewriting, and reworking of them after the congress have been designed to cover the issues of new paradigm of forest economics. We are thankful to the authors for responding positively to our suggestions.

We would like to thank all the authors who have contributed to this volume, and Martin Hostetler, Professor Hans Heinimann, and Professor Yaoqi Zhang for their valuable support in organizing three sessions at the IUFRO Congress. We are also thankful to Nobel Laureate Madam Elinor Ostrom who made a presentation in our sub-plenary session at the congress.

Finally, we would like to thank Springer Publishers and their staff members, specifically Fritz Schmuhl and Takeesha Moerland-Torpey, for taking up this project.

Shashi Kant

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About the Contributors

Stibniati Atmadja is a Post Doctoral Research Fellow at the Center for International Forestry Research in Bogor, Indonesia, with a Ph.D. from the Department of Forestry at North Carolina State University. Her doctoral research was about time preferences, and its empirical links with forest management and health behaviors. She currently works on climate change mitigation research related to Reducing Emissions from Deforestation and Forest Degradation (REDD+) in Indonesia.

Peichen Gong is a Professor of Forest Economics at the Swedish University of Agricultural Sciences. He received his B.S. degree in Forest Science from Shandong Agricultural University, China, in 1986, and his Ph.D. in Forest Economics from the Swedish University of Agricultural Sciences in 1994. He is currently Editor-in-Chief of the *Journal of Forest Economics*. His research covers analytical and numerical analyses of various forest resource management problems including adaptive forestry decision-making under risk and uncertainty, multiple-use management, timber supply, and assessment of forest policy.

Shashi Kant is a Professor of Forest Resource Economics and Management at the Faculty of Forestry, University of Toronto. He is Editor-in-Chief of a book series, *Sustainability, Economics and Natural Resources,* which aims to integrate the concept of sustainability into forest economics as well as reflect the multi- and interdisciplinary nature of economics. He is associate editor of the *Canadian Journal of Forest Research* and *Journal of Forest Economics*. He is the coordinator of IUFRO Research Group on Forest Economics. He has received the Queen's Award for Forestry (2008), the Scientific Achievement Award of Canadian Institute of Forestry (2007), the Scientific Achievement Award of the IUFRO (2005), and the Ontario's Premier Research Excellence Award (2004) for his research.

Martin Kijazi Tanzania Country Researcher, REDD+ Responsive Forest Governance Initiative, a program of The Council for Development of Social Science Research in Africa (CODESRIA) IUCN, SIDA, and University of Illinois at Urbana-Champaign (UIUC). His current projects include comprehensive environmental impact assessment and social impact assessment of extractive industries' (forestry and mining) on local environments and communities, respectively. He is also a sessional lecturer in the Faculty of Forestry, University of Toronto, where he teaches human dimensions of global forestry. He has previously taught other courses related to environment and sustainable development. His research interests include social choice and complexity theory modeling of human–ecosystem interactions. He has done empirical research in Tanzania and Canadian provinces of Ontario and British Columbia.

David N. Laband received his Ph.D. in Economics from Virginia Tech in 1981. He is the author of 9 books and over 100 articles in peer-reviewed journals. His research and teaching interests cover a wide range of topics related to economics and policy. Dr. Laband has been an occasional contributor to the Wall Street Journal and other major North American and Alabama newspapers. He was a Professor of Economics at Auburn University from 1994 to 2012 and enjoyed a joint appointment in the School of Forestry and Wildlife Sciences. Currently, he is Professor and Chair School of Economics, Georgia Institute of Technology, Atlanta, USA.

Bruce Lippke is a Professor Emeritus in the College of the Environment at the University of Washington; former Associate Dean for Research in the College of Forest Resources, Director of the Rural Technology Initiative operated jointly with Washington State University in order to increase technology transfer of newly emerging sciences to rural forest communities; and President Emeritus of an 18 university and professional research organization known as the Consortium for Research on Renewable Industrial Materials (CORRIM). CORRIM is developing life cycle environmental performance measures for every aspect of wood materials and their uses from forest management, processing for products and fuels, construction, use, and disposal.

Karl Gustaf Löfgren is a Senior Professor of Economics at Umeä University, Sweden. He is a former Professor of Forest Economics at the Swedish University of Agricultural Sciences. His research is at present focused on environmental and natural resources, but he has earlier worked in microeconomics, labor economics, and macro economics. His research includes monographs like *The Economic of Forestry* (1985) together with Per-Olov Johansson and *Welfare Measurement in Imperfect Markets* (2004) together with Thomas Aronsson and Kenneth Backlund. His papers include Renewable Resources and Economic Sustainability: A Dynamic Analysis with Heterogeneous Time Preferences with Chuan–Zhong Li and Short-Run Timber Supply and Welfare Gains from Perfect Competition with Peichen Gong.

Suman Majumdar Dr. Suman Majumdar is an Economist at the Center for Government and Public Affairs, Auburn University, Montgomery, USA. He received his Ph.D. in Applied Economics from the Auburn University, USA in 2011. His primary research interest is in natural resource and environmental economics.

Thomas Maness is the Dean, College of Forestry at Oregon State University. He received a Ph.D. in Forest Economics from University of Washington in 1989, a M.S. in Forest Operations from Virginia Polytechnic Institute in 1981, and a B.S.F. in Forest Resources Management from West Virginia University in 1979. His research has spanned three broad categories: (i) strategic land-use planning and forest tenure policy, (ii) value chain optimization, and (iii) energy and climate policy. In addition to his academic accomplishments, Dr. Maness has forestry industry experience in the Pacific Northwest as a Project Engineer and Software Developer.

Elaine Oneil is a Research Scientist at the University of Washington and the Executive Director of Consortium for Research on Renewable Industrial Materials (CORRIM), a 17 university research consortium that has been conducting life cycle inventory and assessments on wood products since 1998. She has a Ph.D. from the University of Washington. She conducts operational research in the fields of life cycle analysis of wood products, carbon accounting, and the integration of current and emerging product markets with the co-benefits that can accrue for climate mitigation and adaptation strategies applied to managed forest landscapes.

Colin Price holds M.A. and D.Phil. degrees in Forestry and Land Economics from Oxford University. He has taught at Oxford Brookes and Oxford Universities, and was formerly Professor of Environmental and Forestry Economics at Bangor University. He is author of "Landscape Economics" (Macmillan, 1978), "The Theory and Application of Forest Economics" (Blackwell, 1989) and "Time, Discounting and Value" (Blackwell, 1993), and about 200 academic papers and book chapters. His major research contributions have been on silvicultural and harvesting economics, diverse branches of environmental economics, and cost-benefit analysis. He holds IUFRO's Gold Medal for Scientific Achievement and is Honorary Fellow of the Scandinavian Society of Forest Economics. His interests include long-distance walking, poetry, cathedrals, and music.

Olaf Schwab is a Senior Economist with the Economic Analysis Division of the Canadian Forest Service, Natural Resources Canada in Ottawa. He received his Ph.D. in Forest Economics in 2008 and his M.Sc. in Forest Resources Management in 2003 from the University of British Columbia, and his B.Sc. from the Georg-August-Universität in Göttingen, Germany in 2000. His main research interests are in the development and implementation of agent-based models for large-scale strategic resource management issues, and the analysis of competitiveness and trade issues related to the Canadian forest sector.

Chander Shahi is an Associate Professor of Resource Economics and Forest Products Marketing in the Faculty of Natural Resources Management at Lakehead University, Thunder Bay, Ontario. He holds a Ph.D. degree from the University of Toronto, besides an MBA and Masters in Forestry and Engineering degrees. His research emphasis has been on economics of public participation and market sector analysis of the forest products industry. He has developed evolutionary game theory and experimental economic models for understanding the behavior of local communities for managing natural resources. Dr. Shahi has also developed integrated models for market readiness analysis for power generation from biomass gasification in Northern Ontario.

Erin O. Sills is an Associate Professor of Forest Economics and Coordinator of International Programs in the Department of Forestry and Environmental Resources at North Carolina State University, as well as a research associate of the Center for International Forestry Research (CIFOR) and the Amazon Institute of People and the Environment (IMAZON). Her research focuses on the economics of multiple-use forest management, including quantifying the value of non-timber benefits from forests, modeling the behavior of households who own or use forests, and evaluating the causal impacts of forest policies on forests and on local welfare.

Runsheng Yin is a Professor of Forest Resource Economics at Michigan State University. His current research focuses on assessing the socioeconomic impacts of China's ecological restoration programs and evaluating the induced changes in such ecosystem services as carbon storage and erosion control. He has been an affiliate of the MSU Center for Global Change and Earth Observation and Center for Global Observatory for Ecosystem Services. In addition to many book chapters, he has published over 50-peer-reviewed articles in more than 20 journals, and edited one book, titled "An Integrated Assessment of China's Ecological Restoration Programs" and two journal special issues in *Environmental Management* and *Forest Science*. Runsheng is one of the few overseas Chinese scholars who have been known for their expertise in China's forest policy and management.

Daowei Zhang is Alumni and George Peake Jr. Professor of Forest Economics and Policy in the School of Forestry and Wildlife Sciences at Auburn University. His research and teaching covers the economic and policy aspects of forest resource management. He is an author or co-author of 5 books, 6 book chapters, and 75 refereed journal articles. His scholarly articles have appeared in *Forest Science*, *Canadian Journal of Forest Research*, *American Journal of Agricultural Economic*, *Canadian Journal of Agricultural Economics*, *Land Economics*, *Economic Inquiry*, and *Public Choice*. He served on the Board of Directors of the *Pinchot Institute for Conservation* and is the recipient of *Award in Forest Science* by Society of American Foresters in 2009.

Yaoqi Zhang is an Associate Professor at the School of Forestry and Wildlife Sciences, Auburn University. He received Ph.D. from University of Helsinki in 2001. Then he worked as a Post-doc Fellow and Research Associate in University of Toronto and University of Alberta from 2001 to 2003. He is broadly interested in natural resource economics, and particularly forest economics. More than 60 articles and book chapters have been published in a variety of journals and academic book series.

Minjuan Zhao is an Agricultural Policy Analyst in the College of Economics and Management (CEM), Northwest A&F University, with expertise of environmental economics, water resource management, and regional development. She has been a faculty member since 1993. To advance her academic career, she pursued her second Ph.D. at the University of Connecticut during 2005–2009, USA. With funding from China's National Nature Science Foundation and Advanced Degree Funding Program, her recent projects have been focused on issues related to water resources in Western China. Dr. Zhao has been the CEM Associate Dean for International Cooperation since April 2010.

Kevin W. Zobrist is a Washington State University Extension Educator serving the North Puget Sound area. Kevin has two forestry degrees from the University of Washington and has spent ten years doing forestry research, education, and outreach. Kevin's top interests are ecology, native trees, and using technology in forestry education.

Chapter 1
Post-Faustmann Forest Resource Economics

Shashi Kant

Abstract This chapter provides an overview of the contents of the volume. To put those contents in perspective, it first reviews recent developments in forest economics and discusses the main problematic features of Faustmann forest resource economics, and the resulting need for a reformed paradigm of forest economics—Post-Faustmann Forest Resource Economics. After these introductory remarks, each chapter included in the five sections of this volume is briefly reviewed.

Keywords Ecosystem services · Faustmann · Forest economics · Green golden rule · Human behavior · Lucas critique · Public choice · Rational · Systems approaches · Sustainability · Time preference

1.1 Introduction

Martin Faustmann's original article "Berechnung des Wertes welchen Waldboden sowie noch nicht haubare Holzbestände für die Waldwirtschaft besitzen" was published in Allgemeine Forst- und Jagd-Zeitung in 1849. The first English translation of this article was published in 1968 by Gane (editor) and Linnard (transl.) as "Martin Faustmann and the Evolution of Discounted Cash Flow: Two Articles from the Original German of 1849" by the Commonwealth Forestry Institute, University of Oxford. Prior to the English translation, this paper was referred by Gaffney (1957), Bentley and Teeguarden (1965), and Pearse (1967). In 1976, Samuelson argued that only Faustmann's Formulation (FF), based on the maximization of Land Expected

S. Kant (✉)
Faculty of Forestry, University of Toronto, 33 Willcocks Street, Toronto M5S 3B3, Canada
e-mail: shashi.kant@utoronto.ca

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Value (LEV), is the correct method to determine an optimal forest rotation, and all other methods, including single rotation method, the IRR approach, and the maximum sustained yield method, are wrong. Since Samuelson's article, the FF has become the foundation of forest resource economics, and four Faustmann's symposia, organized in 1999, 2005, 2009 and 2012 respectively, have provided further impetus for promoting Faustmann Forest Resource Economics (FFRE).

There is no doubt that the FF is correct as long as all the assumptions made to convert complexity into simplicity are satisfied. Samuelson (1976) himself observed that for an unambiguous solution to a problem, certain definite assumptions must be made. Hence, the correctness of an economic model is subject to the validity of assumptions, and there is no absolutely correct economic model. Given this fundamental fact, the outright rejection of other forest rotation methods is not a good example of critical economic thinking. In fact, Samuelson's (1976) arguments are also not flawless. For example, he made an assumption of a perfectly competitive forestland market and argued that the LEV should be calculated as per the FF. If the assumption of a perfectly competitive forestland market is valid, the true value of forestland should be expressed by market transactions and not by the LEV calculations that are subject to so many assumptions. Similarly, Samuelson (1976) either completely missed or intelligently ignored questionable Faustmann's formula and observations for "Sustained Management":

> …then it is obvious from the mathematical principle 'the whole is equal to the sum of its parts', that is correct to say that the land value in sustained management is the same as in the intermittent management and to calculate the stand value by the same formula in both cases.

Nautiyal (1988) demonstrated by a very simple but correct formulation that the optimal forest rotation for sustained management is smaller than the optimal forest rotation for a single stand based on the FF. Similarly, Oderwald and Duerr (1990) demonstrated that the FF is correct only for indivisible capital and not for divisible capital (when a forest can be cut in part while the rest is left uncut for the time being). The whole concept of sustained management (sustained timber yield management) is based on the simple principle that the same timber yield will be available every year, implying that only a part of forest will be cut every year while other parts will be left uncut for harvest in the following years. Unfortunately, most forest economics literature has ignored the correct formulation for sustained management and continued to follow the FF.

Samuelson's paper is a very good example of the conventional and dominant economic thinking—make the strongest possible assumptions to simplify the world and suggest economic models while forgetting and/or ignoring the assumptions at the time of policy and management prescriptions based on those models. The best example of this conventional thinking is the concept of a perfectly competitive market; all economists are well aware that this concept is just a fiction, but hardly any economist, at least from the group of so called neoclassical economists, hesitates in advocating that only markets can allocate resources efficiently. In this advocacy they forget or ignore that only perfectly competitive markets can allocate resources efficiently, and that there is no market that satisfies all the assumptions made to develop the economic model of a perfectly competitive market.

The dominance of this conventional thinking has also led to a common problem in the FF approach-based forest economics—to prescribe the application of a single (FF) approach to all situations irrespective of the specific features of the situation under consideration. For example, the title of Samuelson's (1976) paper is "Economics of Forestry in an Evolving Society" in which he criticized the use of a 4 or 5 % interest rate by Faustmann, Thunen, and Goundrey, and argued for the use of a 10–12 % interest rate. In the context of the current world economy, an argument for the use of a 10–12 % interest rate may seem as stupid as Samuelson thought the use of a 4 or 5 % interest rate was in 1976. Hence, Samuelson ignored the importance and the role of the word "evolving" included in his title, and argued for the same treatment irrespective of the change in economic conditions. Similarly, all forest economists who are followers of the FF approach strongly believe and advocate that only the FF approach is the correct approach for determining optimal forest rotation and other economic decisions related to forest management. These arguments should not give an impression that economist or forest economists are not aware of other issues. For example, Samuelson (1976) recognized the imperfections in capital markets and stated:

> Once we recognize that the enterprise is in an imperfect capital market, we will not be able to deduce its optimal forestry decisions independently of knowledge about its owners' personal preferences concerning consumption outlays of different dates and concerning their "liquidities" at different dates.

Similarly, forest economists are well aware of other limitations imposed by various assumptions of the FF approach, but they continue to ignore those limitations and produce an insurmountable amount of literature using the FF approach. As per a count in 2002, 313 papers were published on the optimal forest rotation since Faustmann's paper, but unfortunately only two papers (Faustmann's and Samuelson's papers) were cited more than 100 times; four other papers more than 50 times each; 127 papers equal to or less than 5 times each, and 93 papers were not cited at all (Newman 2002). This state of forest economics and the treatment of the FF approach is a clear proof of increasing returns in using the FF approach; it has resulted in professional synergies and positive feedbacks in the forest economics profession. One of the key features of positive feedback systems is inefficiencies, and Arthur (1994) and Bowles (2004) made the following observations about inefficiencies in neoclassical economics:

> It encourages use of the standard assumptions in applications where they are not appropriate. And it leaves us open to the charge that economics is rigorous deductions based upon faulty assumptions (Arthur 1994, p xix).

> Its defining assumptions precluded analysis of many key aspects of economic progress, among them the exercise of power, the influence of experience and economic conditions on people's preferences and beliefs, out of equilibrium dynamics, and the process of institutional persistence and change (Bowles 2004, pp. 7–8).

The FFRE is also full of these inefficiencies. In neoclassical economics, these inefficiencies are due to its "locked-in" position in *Chicago man*, while these inefficiencies in the FFRE are due to its "locked-in" position in the FF. There is no doubt that in the past 35 years, many authors have addressed many assumptions of the FF such as imperfect markets and natural uncertainties like forest fires and insect outbreaks. However, the ultimate truth to these studies is the FF, and there is nothing beyond the FF.

Faustmann's paper was published in 1849, 36 years prior to the establishment of the American Economic Association in 1885. Since then the economic, social, environmental and scientific context of forests and forest management has changed by leaps and bounds. For example, in the last few decades the role of multiple forest ecosystem services in climate change, human health, environmental sustainability, and human development is being increasingly recognized, and attention is being focused on enhancing the contribution of forests to a "green" economy rather than the traditional contribution of forests to an industrial economy. Forest management has moved away from sustained yield timber management (SYTM) to sustainable forest management (SFM). Similarly, a new stream of economics—behavioral economics—has moved economic analysis from assumptions-based analysis to actual human behavior-based analysis. Somehow the forest economics profession has not kept the pace with these new and emerging contextual as well as theoretical realities. There have been some efforts to transform forest economics, but not at the desired scale, and now there is an urgent need to take big and concrete steps in that direction.

Kant (2003) made the first attempt in this direction and called for extending the boundaries of forest economics. Since then there have been some efforts in this direction. Wang (2004) proposed an integrative and contextualized knowledge-based two-tier approach for forest economics, and Wang and Wilson (2007) called for pluralism in forest economics. Kant and Lee (2004) argued that forest values are closer to the concept of 'social states' than market price and argued for the use of social choice theory in forest management decisions. Kant and Berry (2005a) included twelve outstanding contributions that demonstrated the applications of various modern economic concepts to forest economics. These included applications of complexity theory by Colander (2005), inter-temporal ethics by Khan (2005), post-Keynesian consumer choice theory by Lavoie (2005), behavioral economics by Knetsch (2005), declining discount rates by Price (2005), social choice theory by Mitra (2005) and Asheim and Buchholz (2005), and nonlinearities and multiple equilibria by Rosser (2005), Vincent and Potts (2005) and Chakrabarti et al. (2005). In the epilogue of this volume, Kant (2005) provided the basic foundations of Post-Newtonian Economics and presented the main differences between Newtonian and Post-Newtonian Economics. Kant and Berry (2005b) included 15 chapters focused on applications of institutional economics to forestry issues. Helles and Vedel (2006), in their editorial for the Journal of Forest Economics, discussed experience economics as an emerging field of forest economics, and Shogren (2007), in his editorial for the Journal of Forest Economics, argued for blending behavioral economics into forest economics to avoid the potential risk of bad policy advice. In 2011, the European Journal of Forest Research published a special issue on Socio-economics in Forestry, and according to the editors, the issue followed Kant's (2003) call for extending the boundaries of forest economics (Schlüter and von Detten 2011). In this issue, Deegen et al. (2011) explain the FF as a model for a forestry of prices, and discuss the numerous limitations of the FF. This special issue contributed to the extension of boundaries, as well as demonstrated the need to continue in that direction.

In some conferences, where the concepts of Kant (2003, 2005) were presented, many forest economists suggested that we, forest economists, should focus on Faustmann Forest Resource Economics and Post-Faustmann Forest Resource Economics (PFFRE) instead of Newtonian and Post-Newtonian Economics. Hence, in this volume, we present twelve chapters that address issues related to forest economics from perspectives different than the traditional forest economics called FFRE. Five of these chapters are focused on issues related to human behavior that is different than the rational economic man or Chicago man, two chapters on public choice theory, two on systems approaches to forest resource economics, and three on incremental approaches to incorporate new features in the FFRE. In future there will, we assume, be many other volumes dedicated to these issues. While the main purpose of this chapter is to provide an overview of the contents of the volume, to put those contents in perspective, a section on the PFFRE is also included.

1.2 Post-Faustmann Forest Resource Economics

The fundamental feature of the PFFRE will be inclusion rather than the exclusion that has dominated the FFRE; this will result in an acceptance of a diversity of economic thoughts and approaches to address the diversity of economic issues related to forest resources arising from diverse natural, social, cultural, and economic contexts. Hence, all established, emerging, and future streams of economics, such as agent-based economics, behavioral economics, complexity theory, ecological economics, experience economics, evolutionary economics, institutional economics, post-Keynesian economics, public choice theory, and social choice theory, will be integral parts of the PFFRE as opposed to their treatment in the FFRE as a pathological specimen in a jar. This integrated body of PFFRE cannot be developed in a single mathematical model like the FF or in a single volume, and the PFFRE will be a completely new economic framework that may take decades to emerge. Kant (2003, 2005) have already discussed many features of the new paradigm of forest economics without calling it PFFRE. Similarly, five key principles of the new paradigm of forest resource economics suggested by Kant (2009) will be very helpful in guiding the future directions of the PFFRE. First, as per these principles, forests are not stands of timber but are ecosystems that include timber. In these ecosystems, different components are not disaggregated but connected and these connections are more important than the individual components. Second, markets are not economics and economics is not markets but economics includes markets. Third, people are neither rational fools nor social morons; they are rational but their rationality goes far beyond the rationality of the selfish economic man. Fourth, a clear understanding of the values of forest ecosystems is critical but values do not mean dollars only; assigning dollar values to ecosystems is not critical, but most critical is changing the value systems of decision makers and others. Finally, the market is only one of many institutions, including governments and communities, for the efficient allocation of scarce resources.

In this chapter, we are not going to discuss details of the key features of the new paradigm proposed by Kant (2003, 2005). However, we will provide a different exposition of Kant's earlier observations and suggestions, as well as a very brief summary.

Kant's suggested features of a new paradigm are deeply rooted in the frequent violations of the basic assumptions of the FFRE that are guided by the assumptions of neoclassical economics. The fundamental assumption of neoclassical economics is *Chicago man* (economic rationality characterized by completeness, reflexiveness, and transitivity of human preferences), which is convenient, successful, and unnecessarily strong, but false (McFadden 1999), and a single *Equilibrium,* which is conceptually simple, analytically strong, but difficult, if not impossible, to exist. The assumption of *Chicago man* is followed by convexity assumptions of utility and production functions, and neoclassical economists have established beyond doubt that if transformation possibilities among goods and services—in and over time—constitute a convex set, price mechanisms may allocate resources efficiently (Koopmans 1957 and Debreu 1959). Given the importance of forest ecosystem services and their role in the green economy, forest economics should address the economic issues related to forest ecosystems and not only the issues related to timber. In this context, forest economists should analyze pathways by which the different constituents of forest ecosystems interact with one another and with external factors such as the economy and society. These pathways in many cases may involve transformational possibilities among forest goods and services that constitute non-convex sets (Dasgupta and Mäler 2004; Crépin 2004). Often the non-convexities result in positive feedbacks in human-forest interactions, and it is well established that in such systems it may be impossible to achieve resource allocation efficiency by means of market prices only. Efficient resource allocation mechanisms would typically involve additional governance regulations, such as taxes and subsidies, quantity controls, and social mechanisms, such as social norms and voluntary regulations and controls (Starrett 1972; Dasgupta and Mäler 2004). Once non-convexities are incorporated into the production systems of forest ecosystems, an optimal harvesting strategy becomes history dependent and, for some states of the forest, more than one harvesting strategy may become optimal (Crépin 2004), resulting in the direct contravention of FF for the optimal forest rotation. Hence, one of the main features of the PFFRE will be the acceptance and incorporation of non-convexities in forest economic systems. This will require moving away from the concept of: (1) a single approach, such as the FF or only a market price-based resource allocation mechanism, to a multitude of approaches for efficient allocation of resources; and (2) a single equilibrium to multiple equilibria and the study of factors that may lock-in the forest economic system in one equilibrium and the factors and processes to move a forest economic system from one equilibrium to other equilibrium.

Similarly, economics is about human interactions and not actions (Deegen et al. 2011). However, the FFRE, similar to neoclassical economics, is based on the utility maximization of an individual rational economic agent, so there is no explicit incorporation of interactions between different agents in the models of the FFRE. In the FF and all other individual action models of economics, interactions are modeled in a way as if single individuals (the forest owner) are not able to influence the complex interactions, but at the most are able to adapt to it (Deegen et al. 2011). The root cause behind this modeling outcome is the assumption that the anonymous behavior of an individual that may be a correct formulation in specific cases such as the production of pencil discussed by Friedman and Friedman (1990). In fact, modeling based on anonymous behavior incorporates unintended, and not intended, interactions. In real life, resource allocation decisions are based not only on anonymous behavior but also on non-anonymous behavior. For example resource allocation decisions with respect to forest management in community forest management and Aboriginal forestry situations are done by non-anonymous interactions between community members. Hence, the action theory based on the individual utility maximization used in the FFRE is only a special case of interaction theory. The PFFRE has to focus on a generalized interaction theory that will include anonymous as well non-anonymous interactions, and intended and unintended interactions. In addition, moving away from the assumption of a rational economic agent will require incorporation of observed human preferences, instead of assumed human preferences, and there is strong experimental evidence about other-regarding and pro-social human preferences from different parts of the world. The incorporation of a range of human preferences in generalized interaction theory will make the task highly complex, but complexity theory and an agent-based modeling approach will facilitate developments in this direction. The ultimate goal of the PFFRE should be a generalized interaction theory, but this may be approached in incremental stages by developing many special cases of generalized interaction theory. Hence, the PFFRE will be fundamentally different from the FFRE; the key differences are summarized in Table 1.1.

Given these differences, the PFFRE should be able to capture different orientations of human behavior, different contextual situations, different measures of economic efficiency, and different resource allocation mechanisms. Incorporation of such behavioral, contextual, efficiency, and mechanisms diversities will be possible in economic models that are based on the "both-and" principle that has been accepted by post-Newtonian physicists of the twentieth century rather than economic models based on "either-or" principle, the guiding principle of the FFRE. Under the umbrella of the "both-and" principle, Kant (2003) has proposed four sub-principles: existence, relativity, uncertainty, and complementarity. Understanding of these sub-principles will definitely help in making inroads towards the PFFRE. The 'principle of existence' suggests that we cannot ignore the relevance of situations which have survived for a long time. Hence, we should focus first on achieving an economic understanding of the existing human-forest interactive systems, in order to be able to

Table 1.1 Main differences between the FFRE and the PFFRE

Feature	FFRE	PFFRE
Forest	Source of timber only, and treated as disaggregated components	Source of multiple values, and treated as forest ecosystems
Agents	Rational economic man and homogeneous agents	Social agent (homo-sapiens), and heterogeneous and versatile agents
Approaches	Single FF approach based on non-cooperation	Multiple approaches based on cooperation as well as non-cooperation
Basic foundation	FF and neoclassical economics	All streams of economics such as agent-based economic models, behavioral economics, complexity theory
Basis	Newtonian physics	Evolutionary biology and quantum physics
Equilibrium	General equilibrium	Multiple equilibria and non-equilibrium
Feed-backs	Negative	Negative as well as positive feedback, path dependence, and inefficiencies
Holy trinity	Rationality, greed, and equilibrium	Purposeful behavior, enlightened self interest, and sustainability
Human interactions	Anonymous, unintended interactions through market clearing prices and contractual obligations	Anonymous as well as non-anonymous, unintended as well as intended interactions through market and non-market mechanisms, respectively, and non-contractual social obligations
Institutions	Either no institutions, or formal institutions, are represented by a budget constraint, no role of informal institutions, institutions do not change	Outcomes are dependent on institutional setting, optimal institutions are not freely available; role of formal as well as informal institutions, and institutions evolve over time.
Learning and emotions	No learning and no emotions	Learning from others, frequency-dependent learning, and emotions may produce a behavioral response
Modeling	Modeling of decision outcome	Modeling of decision (cognitive) process as well as outcome
Needs and wants	No difference between needs and wants	Difference between needs and wants, satiable needs, hierarchy of needs, and growth of needs
Nirvana	Possible if there are no externalities and all had equal abilities	Not possible, externalities and inequalities are driving forces, systems constantly unfolding

(continued)

Table 1.1 (continued)

Feature	FFRE	PFFRE
Preferences	Exogenous (as imposed by economists), self-regarding, and fixed preferences	Endogenous, reference- dependent, self as well as other-regarding and/or social preferences
Principle	Maximizing	Satisfying
Rationality and information	Mathematical or constructivist rationality and full information	Procedural and/or ecological rationality, and incomplete information
Returns to scale	Constant and decreasing returns to scale	Constant, decreasing, and increasing returns to scale
Society	Aggregation of homogenous agents	Heterogeneous agents, similar populations may have different norms, tastes, and customs, resulting in local homogeneity and global heterogeneity
Solutions	Closed form solutions	Simple closed form solutions are not necessary; indeed, any solutions that are susceptible to simple interpretations may not exist
Subject	Structurally simple, deterministic, stable	Structurally complex, structures are constantly coalescing, decaying, and evolving. All this is due to externalities leading to jerky motions, increasing returns, transaction costs, and structural exclusions
Sustainability	Sustainability of the FFRE and the followers of the FFRE	Sustainability of society and forest ecosystems
Time, age, and generations	Positive discounting, no role of age and generations	Zero, positive, and negative discounting, individuals can age, generational turnover becomes central, age structure of populations change, and generations carry their experiences
Utility	Scalar utility, convexity, and expected utility theory	Vector utility, convexity as well as non-convexity, prospect theory and libertarian paternalism
Uncertainty	Risk	True or Keynesian uncertainty

Note This table is similar to a table in Kant (2005)

predict whether the effects of proposed changes would be, on balance, positive or negative. The ‘principle of relativity’ suggests that optimal solutions are not universal but rather context specific; in many cases, they will involve important non-market mechanisms such as social and cultural norms, and social and political choices. The ‘principle of uncertainty’ suggests that due to uncertainties in natural and social systems, a social agent may typically not be in a position to maximize his outcomes, but will rather search for positive outcomes and learn by experience, such that resource allocation will be improved by adaptive efficiency, in which cumulated effects over time are likely to be more important than that of the achievement of allocative efficiency at each point of time. The ‘principle of complementarity’ suggests that human behavior combines both selfish and altruistic elements, that people have both economic and moral values, and that people need forests to satisfy both lower level and higher level needs. This principle also suggests that the PFFRE will be based on complementarity between different streams of economics such as behavioral economics, complexity theory, and neoclassical economics. Hence, the PFFRE will not exclude neoclassical economics or the FFRE but it will include those aspects of the FFRE which are relevant and useful to the current context of forest resources.

Given the importance of the correct understanding of human behavior in forest resource economics, this volume starts with a section on human behavior and forest resource economics, and the first chapter in this section addresses the key question: are forest user groups rational economic or social agents? Similarly, given the importance of the useful concepts of the FFRE, the last section of the volume is focused on incremental approaches to make some approaches of the FFRE relevant and useful to the current context. The volume closes with a chapter on the reexamination of the FF in the current context of forestland markets. In between, four chapters on human behavior, two chapters on public choice theory, two chapters on systems approaches, and two chapters on incremental approaches are included.

1.3 Human Behaviour and Forest Resource Economics

The previous section was designed to give a broad introduction to the PFFRE. This section draws on the other chapters of the volume to delve deeper into the specific aspects of human behavior—the foundation of the PFFRE. Human behavior is the fundamental base of the FFRE, but as stated earlier in the FFRE, human behavior is treated as exogenous and every human being is assumed to be an economic rational man and all human beings are assumed to be homogenous with respect to their economic behavior. Hence, the fundamental question is: is this assumption about human behavior correct or not?

In the first chapter of this part, Shahi and Kant answer this fundamental question by presenting the results of an asymmetric public good game, termed the Joint Forest Management game, conducted with forest user groups in 38 villages of the Himachal Pradesh and Gujarat states of India. In the organization of the game, user groups were divided in four categories—rich, poor, landless, and women, and four treatments—no communication, face-to-face communication, light punishment to defectors and heavy punishment to defectors. User groups expressed preferences different than the preferences of a rational economic agent in 70 % of cases in Gujarat and 85 % of cases in Himachal Pradesh. A majority of the user groups expressed mixed preferences—preferences between pure self-regarding and pure other-regarding preferences. There was a wide variation in preferences across the four user groups. Face-to-face communication and punishment of free riders were found to increase cooperation, but rich groups were less deterred by punishment. In this experimental field, and not in the laboratory, evidence of the diversity of preferences across forest user groups, ranging from pure self-regarding to pure other-regarding preferences, confirms that we cannot continue to build forest resource economic models using the assumption of the rational economic agent, and the incorporation of the diversity of human preferences into forest resource economic models should be the top priority of the PFFRE.

Once the diversity and dynamic nature of human preferences is recognized, economics has to switch from an efficiency-and-control story to a complexity-and-muddling through story (Colander 2005). The complexity story is not characterized by a single equilibrium, but by basins of attractions, and in that theory economic optimality means remaining either in the existing basin of attraction or going to a more desirable basin but avoiding less desirable basins (Colander 2005). In the second chapter of this section, Kijazi and Kant present the use of complexity theory to test the different values of five categories of actors (foresters, environmentalists, park-authorities, entrepreneurs, and local communities), and their interactions with institutions towards sustainable forest management (SFM) in Mount Kilimanjaro, Tanzania. Chaos theory is used to analyze values data. The results reveal that formal and informal organizations and institutions they promote serve as attractors that shape evolving preferences of actors. The diverse and dynamic preferences of heterogeneous actors are observed, and it is found that many economic and moral values oscillate in the positive basin of attraction/optimization—indicating their complementary nature. This chapter's analysis, similar to the previous chapter's results, confirms that actors behave in the manner of a so-called 'socially-rational agent', rather than the self-interest maximizing agents of the Faustmann model. Institutionally, informal advocacy coalitions with actors from different formal work organizations, but with shared values towards SFM, are found. These coalitions are coupled with a strong positive valuation of co-operative (participatory and collaborative) arrangements of SFM vis-à-vis conventional centralized forest management. While SFM values limit-cycles oscillate in more stable and desirable basins of attraction, institutional limit-cycles show more chaos. The latter outcome suggests that continued SFM institutional reforms, rather that mere value sensitization, are critical ingredients in achieving SFM.

In real life, human beings can learn from their experiences, and can modify their preferences and decision processes accordingly. In the FFRE there is no role for learning from experience, and human beings are trapped for life in the box of economic rationality. Schawb and Maness, in the third chapter of this part, extend the analysis of the diversity of preferences and context by modeling industry interactions and strategic decision making in an environment that is characterized by continuously changing conditions in both the underlying resource inventory and finished product markets. In this chapter, economic agents are firms and not individuals, and the agent-based forest sector modeling framework (Cambium), in which decision processes are modeled using an implementation of the self-tuning experience weighted attraction learning algorithm (EWA-Lite), is used for analysis. This algorithm allows agents to adjust their learning behavior along a continuum between reinforcement learning and belief learning depending on the perceived stability of their environment. In this model, the number and relative size of competitors is determined by repeated agent interactions which are interpreted as an emergent property of the inventory, industry, and market system. The authors present and discuss results from a 200-year simulation of 15 sawmilling agents on a hypothetical 3.3-million hectare land base in British Columbia, Canada. The inclusion of autonomously interacting agents allows for a departure from a purely mechanistic world view of the FFRE and economics in general, helping to achieve and analyze a more realistic view of an emergent world.

Other critical aspect related to human behavior is the time preferences of economic agents and, as per economic theory, decisions with long-term pay-offs, such as investment in forest management, are influenced by the time preferences of agents. In the FFRE and neoclassical economics, time preference, or the rate of discount for all individuals, is assumed to be the same and determined by capital markets. Atmadja and Sills, in the fourth chapter, relax the assumption of exogenous discount rates and use binary choice questions to elicit individual discount rates, examining the relationship between forest management behavior and personal discount rates. These individual discount rates and relationships are examined for “limited resource woodland owners” in the southern United States, including landowners who are traditionally underserved by public institutions (i.e., minorities and women) and who face financial, social and natural resource constraints that limit their forest management options. The authors find that the probability of harvesting timber is positively related with personal discount rates, as predicted by theory. However, discount rates are not significantly related to stand improvements or contact with a professional forester, suggesting that lack of investment in forest management is not a result of landowner impatience. Rather, these behaviors are driven by characteristics such as the size of property, proximity of residence to woodlands, and tenure characteristics including whether the woodlands are inherited. The diversity in discount rates across the forest owners and the diversity in the relationships between individual discount rates and forest-related investment decisions further enhance the case of the PFFRE based on complexity theory rather than on the conventional efficiency theory.

Price, in the fifth chapter of this part, presents ethical and conscience-based behavioral perspectives about the time preferences of human beings. He argues that human impatience and the inconsistency between affective and cognitive views of “otherness” undermine the foundations of sustainable forest management, with modern economies having induced institutions that reinforce this tendency. However, it was not always the case. In the past, the ethos of societies and nations supported long-term productivity against short-term interest. Individualistic ethics, the main outcome of the neoclassical economic construct, have internalized long-term well-being within present mental constructs, and current models of self-interest have been projected as possessing intrinsic ethical merit.

However, the use of discounting by financial institutions is undermined by the institutions' actual performance. The law may accidentally assist sustainability by its universality. Commonality of interest is only efficacious for future interests if supported by a further ethical requirement, but conforming with this requirement may encourage later generations to do so too. Some reinforcement of conscience-based behavior may be derived from religion, mutual censure, art, academic integrity and pre-commitment, and by regarding sustainability as a present good. Hence, Price highlights the role of social, cultural, and religious institutions in forest resource economics. To incorporate these institutions in economic analysis, forest economics has to move from the FFRE to the PFFRE.

1.4 Public Choice Theory and Forest Resource Economics

The applications of economic theories and methods to analyze political behavior is known as public choice theory, and its founding fathers are Kenneth Arrow, Duncan Black, James Buchanan, Gordon Tullock, Mancur Olson, and William Riker. Public choice theory rests on the economic model of rational behavior and assumes that people's behavior in the political process or collective choice process is guided by their own self-interests. This treatment of political agents has two implications. First, the individual becomes the fundamental unit of analysis, meaning that groups do not make choices, only individuals do. Second, public and private choice processes differ due not to the motivations of actors but to stark differences in the incentives and constraints in the pursuit of self-interest in the two settings (Buchanan and Tullock 1962). In the case of private choices, the decision is voluntary and a bargain will be struck only if both buyer and seller are made better off, but in public choices, there is no guarantee that everyone's welfare will be improved (Buchanan and Tullock 1962). Hence, even the public choice theory is based on the same assumption of human behavior, as assumed in neoclassical economics, but it may provide substantially different economic implications when used for the analysis of forest policies. In this part of the volume, two chapters present the applications of public choice theory to forest resource economics.

In the first chapter of this part, Laband argues that, similar to private markets, there are political markets, and Adam Smith's recognition of the human propensity to 'truck, barter, and exchange' also applies to political markets. Hence, with the increasing recognition and appreciation for the multiple values of forests, some of which are public goods, our understanding of forest resource economics will be enhanced by explicitly incorporating principles of decision-making in a collective market context—public choice analysis. The self-interested behavior of politicians (elected), bureaucrats (unelected), and voluntary associations of individuals (NGOs), combined with the agency problems inherent to representative government, has strong implications for the decision-making environment of private timberland owners. Timber growers make decisions that span (perhaps several) dozens of years, and long-term decisions, made even under conditions of scientific certainty, necessarily are made in a context of political uncertainty. This political uncertainty, therefore, must be integrated into models of forest resource economics.

Zhang, in the second chapter of this part, demonstrates that policy-making does not exist in isolation of political and social structures, and that the outcomes of theoretical economic models are greatly influenced by these structures. The analysis presented in this chapter demonstrates that interest group politics and political contributions have worked in the U.S. political and institutional settings and that the results are an inefficient forest products trade policy. Hence, a simple neoclassical economic analysis of international trade and/or international markets is insufficient to explain real world situations, and to better explain, anticipate, and predict the outcomes of various forest policy developments, forest economists have to complement their traditional economic analysis tools with public policy analysis tools and other similar tools.

1.5 Systems Approaches to Forest Resource Economics

As discussed in Sect. 1.2 of this chapter, forests are not stands of timber but ecosystems that include timber. In these ecosystems, different components are not disaggregated but connected and connections are more important than individual components. This requires the use of systems approaches, the fundamental blocks of ecological economics, to forest resource economics. In this section, two chapters present the applications of systems approaches to forest resource economics.

In the first chapter, Yin and Zhao argue that ecological restoration programs (ERP) and payments for ecosystem services (PES) are inherently linked and should be treated as integrated social-ecological systems (SES), but they have been largely pursued by restoration ecologists and socioeconomic scientists separately, which is not conducive to the achievement of their common goal—sustainable ecosystem management. The authors discuss the potential limitations in the current ERP and PES research and call for truly integrated and more relevant studies to provide effective guidance to ecological restoration and ecosystem management. The authors propose a systems framework that integrates social and ecological processes, and use it to analyse China's recent experience in converting degraded cropland. Their analysis demonstrates the need for and possible ways of treating both ERP and PES as part of an integrated process of forest ecological restoration and ecosystem management.

In the second chapter, Lippke, Oneil, and Zobrist demonstrate the use of life cycle analysis in moving away from the traditional reductionist approach to a systems approach in forest resource economics. The authors argue that Life Cycle Inventory and Analysis (LCI/LCA) can be used to track carbon and other services from the forest to products, including displacement of fossil emissions when wood substitutes for fossil fuels or fossil-intensive products are used. They apply life cycle analysis to identify leverage points in reducing carbon emissions and their impact on old forest habitat as the ecosystem value most likely threatened by carbon mitigation incentives. In theory, incentives that do not target uses that displace the most emissions will likely steal the feedstock from less effective uses, increasing rather than decreasing emissions. The authors find that ethanol subsidies, forest carbon credits, and renewable energy standards steal the feedstock from higher leveraged uses, while a carbon tax effectively penalizes the largest emitters. Either carbon taxes or incentives will affect the cost of sustaining critical habitat. They observe that while a carbon tax provides the proper price signal, with the highest reward for the greatest carbon emission reduction, increasing habitat values may be justified to support the production, maintenance and restoration of important habitat. The authors suggest that institutions need to consider life cycle implications to sustain forests and their multiple values.

1.6 Increamental Approaches to Forest Resource Economics

The PFFRE, as discussed in the second section of this chapter, will be inclusionary and not exclusionary, and therefore it is important that the useful concepts of the FFRE should be made relevant to the current situations of forest resources, forest management, and forest economics. Some concepts of the FFRE can be made useful and relevant by incremental approaches. In this part of the book, three chapters demonstrate how the usefulness of some concepts of the FFRE can be enhanced by incremental approaches.

In the first chapter of this part, Lofgren and Gong present a method to address the standard problem of the neoclassical economic framework of policy analysis, known as the Lucas Critique. In the case of timber supply, policy changes have two potential effects: a change in the relationship between the quantity of timber harvested and its determinants, and a change in the values of the factors that influence timber supply. A standard neoclassical approach for policy evaluation is to estimate the supply function from observed harvest behavior, and then use the obtained supply function to simulate the effects of policy changes. The Lucas Critique points to a limitation of this approach: it cannot capture the first effect of policy changes on timber supply. The authors present a new approach to estimate the timber supply function by introducing two applications in counterfactual comparisons. The approach seeks to optimize the supply function parameters under a given set of policy conditions. In the first application, the authors determine the change in the supply function following a change of the market regime and measure the welfare gain from competition in the timber market. In the second application, they examine the effects of tree improvements on the timber supply function and on the producer and consumer surplus. The results from the second application show that ignoring the change in supply functions leads to significant underestimation of the welfare effects.

In the second chapter of this part, Kant and Shahi present the extension of the Green Golden Rule (GGR) from a single stock to multiple stocks. The authors argue that, generally, a forest has multiple types of stocks/cohorts—stocks of different ecological attributes and age classes—that provide different goods and services, and these goods and services are valued differently by different user groups. Hence, the aggregation of all stocks into a single stock is unable to capture the complexities of forest growth, user groups' preferences, and their implications for sustainable management of these resources. Sustainable management of forest resources requires optimal consumption as well as an optimal level of conservation of each type of stock separately. Hence, the authors develop optimal conditions for conservation and consumption for a forest comprised of three differentiable stocks, and generalize these conditions for any number of stocks greater than three. These optimal conditions are termed as the Enhanced Green Golden Rule (EGGR). The EGGR provides more distinct optimality conditions than the GGR for all stocks except the terminal stock.

In the final chapter, Zhang and Majumdar argue that Land Expectation Value (LEV), Internal Rate of Return (IRR), Wage Expectation Value (WEV) and Profit Maximization (PM) approaches for optimization of forest rotation age are essentially similar in maximizing the residual value but different in terms of the receiver of residual value. In the long run, the residual value (loss) is created by all four factors (land, capital, worker, and entrepreneur) and is shared depending on relative market powers and scarcity of these factors. In the increasingly active timberland markets, the role of entrepreneurs and investors in land management and the scale issue are becoming important but are not addressed in the LEV approach. Therefore, the authors argue that profit maximization might be a more general and suitable approach in addressing optimum land size and rotation since it can incorporate both scale of land and capital (management input) in the objective function. In other words, profit maximization would be able to cope with the scale of capital, land, and rotation simultaneously.

1.7 Conclusion

In this chapter, as well as in other chapters of this volume, there are strong arguments to make fundamental changes in the profession of forest resource economics, and transform it from the FFRE to the PFFRE. None of the chapters include a PFFRE model, but every chapter provides some inputs to the PFFRE. Some readers may be disappointed by the absence of such a model, but that is going to be the fundamental difference between the FFRE and the PFFRE. As discussed in the first two sections of this chapter, the PFFRE will be inclusionary, and it will include all relevant and useful economic thoughts and streams and their use for economic analysis of forestry issues. Hence, the PFFRE will be evolutionary in nature and cannot be closed in a fixed-size box or in a single fundamental mathematical model. In other words, the PFFRE will be a landscape of forest resource economics and not a stand like the FFRE. As usual this landscape will be composed of various types of stands, and these stands will emerge and develop over many decades. The papers included in this volume can be thought of as few species and their varieties which will be the elements of some stands of the landscape.

We understand that the task of transforming a well-established paradigm is always challenging, and to some hard-core Faustmann forest economists these issues may not make any sense. That is perfectly fine because the transformation becomes more ardent in the case of positive feedback systems. In these systems, a stable equilibrium cannot be displaced by small deviations from the equilibrium due to self-reinforcing forces, and only external shocks of the magnitude of revolutions can move the system from a stable equilibrium to other equilibria. External shocks with large magnitudes, but not enough magnitude to move the system from the current equilibrium to the desired equilibrium, will result in a punctuated equilibrium. Based on the evidence presented in Sect. 1.2 of this chapter, it seems that forest resource economics has started moving towards the first punctuated equilibrium. We hope that once forest economists start observing increasing returns in this new punctuated professional equilibrium, the magnitude of shocks will increase exponentially and the profession will completely move to this new equilibrium of PFFRE.

In closing, we would like to remind the readers that the basic need to transform forest resource economics has arisen from the fundamental changes in people's value systems with respect to forests and changes in forest management from sustained yield timber management to sustainable forest management. The changes in the economics profession, such as the emergence of new streams of economics, have provided the impetus for changes in forest resource economics. Hence, the contributors to the PFFRE should remember these two driving forces of change. Finally, we are very optimistic about this transformation of the profession and we seek the support and help of every person interested in economic issues related to forests.

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Part I
Human Behaviour and Forest Resource Economics

Chapter 2
Are Forest User Groups Rational Economic or Social Agents? Experimental Evidence from India

Chander Shahi and Shashi Kant

Abstract The key pillar of Faustmann's forest economics that individuals have only self-regarding preferences was tested. An asymmetric public good game, termed the Joint Forest Management game, was used to test user groups' preferences for forest management. User groups were divided in four categories—rich, poor, landless, and women. Field experiments were conducted in 38 villages in Gujarat and Himachal Pradesh states of India under four different treatments—no communication, face-to-face communication, light punishment to defectors and heavy punishment to defectors. In Gujarat, in 70 % of cases, and in Himachal Pradesh, in 85 % of cases, user groups expressed preferences different than the preferences of a rational economic agent. The percentage of user groups with pure other-regarding preferences was also small. A majority of the user groups expressed mixed preferences—preferences between pure self-regarding and pure other-regarding preferences. There was a wide variation in preferences across the four user groups. Face-to-face communication and punishment of free riders was found to increase cooperation, but rich groups were less deterred by punishment. The recognition of the diversity of preferences, ranging from pure self-regarding to pure other-regarding, and their variation across the user groups, is one of the key elements of Post-Faustmann forest economics, and should be incorporated into economic theories and resource management policies and strategies. Policy makers also need to focus on alternate means to meet the subsistence needs of poor villagers, especially women and landless people, to strengthen cooperative behavior of these user groups with respect to forest management.

C. Shahi (✉)
Faculty of Natural Resources Management, Lakehead University,
955 Oliver Road, Thunder Bay, ON P7B 5E1, Canada
e-mail: cshahi@lakeheadu.ca

S. Kant
Faculty of Forestry, University of Toronto, 33 Willcocks Street,
Toronto, ON M5S 3B3, Canada
e-mail: Shashi.kant@utoronto.ca

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2.1 Introduction

One of the key pillars of Faustmann's forest economics and neo-classical economics is a representative "rational economic agent" who has only self-regarding (SR) preferences irrespective of their outcomes. A Nash Equilibrium, an outcome of these preferences, may be socially undesirable in many situations such as management of common pool resources—forests, fisheries, and environment—that is termed "the tragedy of commons". The rational economic agent is unable to learn from the disastrous outcomes of its SR preferences, its context, and better outcomes from other categories of preferences. Sen (Sen 1977) called such an economic agent a "rational fool" and Hegel (Hegel 1967) termed him/her a "mindless individual". Irrespective of many such limitations of the rational economic agent suggested by many great economists, neo-classical economists have not shown any tendency to modify their assumptions, and reasonably so, because their whole paradigm is based on these simplistic assumptions.

Fortunately, during the last two decades or so, a new emerging field of economics—Behavioral Economics—has provided ample experimental evidence from around the world that human beings have preferences other than the SR preferences, such as other-regarding (OR) and pro-social (PS) preferences. Behavioral economists have proposed many economic theories to explain human preferences that go beyond the self-interest hypothesis and have categorized these preferences into pure altruism (Andreoni and Miller 2002), impure altruism (Andreoni 1989), inequality-aversion (Fehr and Schmidt 1999), reciprocity (Falk and Fischbacher 1999), self-reputation (Bénabou and Tirole 2004), and institutional-context-based preferences (Ostrom 2000). These studies, in general, have recognized the endogenous and heterogeneous nature of human preferences. For example, Andreoni and Miller (2002) found that 47 % people have SR and 53 % have OR preferences. Similarly, Fischbacher et al. (2001) found in a public good game that 30 % people behave like free riders and 50 % as conditional co-operators. These findings of behavioral economists have also motivated game-theory economists to incorporate real life processes such as learning and imitation of human behavior in evolutionary game-theoretic approaches of economic analysis. For example, in repeated plays of a game, players adapt their behavior through learning and copying successful strategies, and view equilibrium as the outcome of an adjustment process, a realistic version of human interactions (Fudenberg and Levine 1997; Samuelson 1997).

The most commonly used games in behavioral economics are the Dictator's Game, Ultimatum Game, and Trust Game. Some economists have also used

Common Pool Resource (CPR) games, but most of these games have been conducted in labs, where the subjects were university students and the results of these experiments were simulated to predict the behavior of local communities. Economists have predicted cooperation as equilibrium through these lab experiments (Axelrod 1984; Ostrom 2000) and shown that self-governance can emerge and be sustained (Ostrom 1990; Ostrom et al. 1994). Some economists (such as Molinas 1998 and Cardenas 2003) have also conducted games with community members. The number of such field experiments is very limited and there are many unexplored aspects of preferences of user groups of different resources such as forests that need to be studied for a better understanding of economic and managerial aspects.

In this chapter, our focus is on the preferences of forest user groups from India. In developing countries, like India, a large population of local communities depends on forests for their day-to-day requirements of fuelwood, small timber, fodder and other non-timber forest products. Hence, the exclusion of local communities from forest use is almost impossible, and exclusionary policies have been the main reason for deforestation and forest degradation in these areas. In the last three decades, many developing countries, including India (Kant, 1996, The economic welfare of local communities and optimal resource regimes for sustainable forest management, "unpublished"; Kant 2000; Kant and Berry 2001), Nepal (Mathema 2004), China (Xu et al. 2004), Mexico (Klooster 2000), Ethiopia (Gebremedhin et al. 2003) and Cambodia (Marschke and Nong 2003) have tried to resolve this problem by involving local communities in forest management. These programs are known as Joint Forest Management (JFM), Co-management, or Community-Based Forest Management. In India, two main features of these programs are: (1) forest managers, normally state agencies, seek the cooperation of local communities in forest protection and forest management; and (2) local communities are ensured, by forest managers, of a share in the final harvest of timber in addition to an annual harvest of non-timber forest products and wages for their forest protection and management work. Even with the uniform provisions of these programs, the success of the programs varies across communities.

Our basic premise is that forest user groups' preferences for cooperation or non-cooperation with respect to forest resource use are endogenous preferences, and these preferences will not be homogenous across user groups. For example, highly-dependent forest user groups may have quite different preferences than less-dependent user groups. The types and distribution of user groups and their preferences with respect to cooperation in forest management will lead to different outcomes of the same institutional arrangement across different communities. Hence, an understanding of the preferences of different user groups with respect to forests is critical for analyzing the outcomes of the JFM program and making appropriate managerial interventions.

In order to study different user groups' forest preferences, we used an asymmetric public good game, where the payoff of each individual depends on his own action and on the actions of others. These games were organized in two states of India—Gujarat and Himachal Pradesh. The two states were selected to capture social, economic, and resource diversity. Gujarat is one of the richest states of India, and therefore has a higher degree of market integration. Gujarat's forests are deciduous while the forests of Himachal Pradesh are evergreen coniferous. We conducted repeated rounds of the game under four different treatments—no communication, face-to-face communication among participants between different rounds of the game, light punishment for non-cooperators and heavy punishment for non-cooperators.

As far as we know, the organization of the games presented in this chapter is unique. Normally, participants in public good games or any other economic game are individuals. In the planning stage of our study, we planned to conduct these games among individuals from different user groups. However, when we visited different villages in these two states to organize these games, community members refused to participate individually in the games, and told us that they would like to participate as a group representing their respective user groups. Based on our discussions with community members, we identified four user groups—rich, poor, landless, and women. Hence, in our public good games, preferences were revealed by a group of people, after discussion and reaching consensus among themselves, representing different forest user groups of a village. In this chapter, therefore, we present the analysis of collective preferences of four user groups and not the preferences of individual members from four user groups.

The theoretical aspects of the JFM and a payoff matrix of the JFM game are presented in Sect. 2.2. The details of the field experimental design are given in Sect. 2.3. Section 2.4 discusses the results of the field experiments. Conclusions and suggestions for management of forest resources are given in Sect. 2.5.

2.2 Theoretical Aspects of Joint Forest Management and the Payoff Matrix of the JFM Game

JFM is forest management in which representatives of a government agency (forest managers) reach an agreement with the representatives of local community with respect to the protection and maintenance of a given public forest area. The agreement defines the rights and duties of both the players (the government and the local community). Generally, the local community receives: (1) a fixed share of the net value of the timber harvest at the end of a rotation period; (2) the right to collect all non-nationalized non-timber forest products (NTFPs) (such as fuel-wood, fodder, edible berries and plants, wild mushrooms, medicinal and herbal plants); (3) government wages for community labor towards the protection and maintenance of the forest resource. The local community has a duty to practise self-restraint, to avoid illegal harvesting of timber and over-exploitation of non-timber resources, and to keep a watch on the forest to protect it from outsiders. In case of a community's non-compliance of its duties, such as illegal harvesting, the government collects fines from the community members that are caught.

In addition, the government receives the remaining share of the net value of timber harvest at the end of the rotation period and an annual return from nationalized NTFPs.

Although the representatives of the community may sign the agreement and decide to cooperate as a group with government officials for preserving and proper management of forest resources, individual members of the community may refuse to cooperate depending on preferences that may be influenced by their economic conditions, social status, and dependence on forests. Therefore, in the JFM, community members can be either cooperators or defectors. In addition, some community members also take the role of enforcers. The payoffs of these three categories of members are different as explained next.

Cooperators: These are the people in the community who abide by the JFM agreement and do not resort to practices that are illegal under the JFM agreement. In turn, they get a share from the final timber harvest in addition to a proportional share from all the non-timber forest products.

Defectors: These are the people in the community who do not abide by the JFM agreement and resort to illegal removal of forest products that is not allowed under the agreement. On being caught, they are not given any share from the final timber harvest, but they cannot be excluded from community development activities because these activities are of public nature. Since collection of non-nationalized non-timber forest products is allowed under the agreement, they collect those products as would any other member of the community.

Enforcers: These are the people, authorized by the forest protection committee (FPC), who act as watchmen and are responsible for the enforcement of the JFM agreement. They are paid wages for their work. Therefore, enforcers are the people in the community who abide by the agreement and are also responsible for enforcing the provisions of the agreement on the community by sanctioning the defectors. Each enforcer receives the same payoff as a cooperator. In addition, enforcers get a reward from the share of fines collected from the defectors, however, enforcers have to bear a cost for sanctioning the defectors.

Suppose R_i is the annual payoff (net of labor cost) from illegal removals of forest products from forests, R_f is the annual fine (value of forest products and punishment for theft) paid by an illegal harvester if he is caught, and p is the probability of being caught by a forest manager, which is normally very small. The net annual payoff of a person who removes illegal forest products from the resource is $(R_i - pR_f)$. Further suppose R_t is the total annual payoff (an annual equivalent) from the final timber harvest, R_n is the total annual payoff obtained from non-timber forest products, R_w is the payoff of the enforcer from annual wages for protection and maintenance of the resource, R_r is the annual payoff of the enforcer from rewards, and R_c is the annual cost of the enforcer in sanctioning the defectors. The annual cost of the enforcer consists of two components—annual fixed costs (F_c) incurred by the enforcer, whether he sanctions a defector or not, and variable costs (V_c) per unit catch for extra time spent on catching and sanctioning a defector. Suppose s is the share of the community from the final timber harvest, a part of this share, s_1, is used for providing common infrastructural and other community development facilities to the community and the rest, s_2, is equally distributed among the cooperators and enforcers. The annual payoff of each type of agent is given by

$$\text{Payoff of a cooperator, } \pi_{c_i} = \frac{s_2 R_t}{(s_c + s_e)n} + \frac{R_n}{n} \tag{2.1}$$

$$\text{Payoff of a defector, } \pi_{d_i} = \frac{R_n}{n} + (R_i - pR_f) \tag{2.2}$$

$$\text{Payoff of an enforcer, } \pi_{e_i} = \pi_{c_i} + \frac{R_f s_d}{s_e} - \left(F_c + \frac{V_c s_d}{s_e}\right) + R_w \tag{2.3}$$

Where, $\frac{R_f s_d}{s_e} = R_r$ is the share of reward of each enforcer.

Shahi and Kant (2007) formulated an n-person asymmetric game using these payoffs, and used the concepts of evolutionary stable strategies and asymptotically stable states to analyze the variations in the JFM outcomes. However, one of the limitations of these payoff structures is that an individual's payoff is treated as the function of his/her efforts only. In the case of common pool resources, such as forests, the payoff from illegal felling of the defector (R_i) depends not only on the extraction effort of the defector but also on the extraction efforts of other defectors. The individual's payoff from a forest is increasing with one's effort of extraction of forest products, but decreasing with the aggregate extraction efforts of others. Hence, player i's payoff from illegal felling, R_i can be expressed as:

$$R_i = \left(ax_i - \frac{1}{2}bx_i^2\right) + K\sum(x_{\max} - x_{others}) \tag{2.4}$$

where a, b, and K are strictly positive and depend on the type of forest resource. x_i is the effort exerted by an individual to illegally remove forest products, x_{max} is the maximum effort exerted by an individual and x_{others} is the effort exerted by all other players for illegal removal of forest products. The concavity of the function indicates diminishing marginal private returns to effort exerted in illegally removing forest products.

The main objective of this study was to understand the preferences of different user groups, so we incorporated only cooperators and defectors in our game and ignored enforcers. The game was designed to be played among five players (user groups) and each player can choose an effort level of 0–5. The players who choose 0 effort are cooperators as they do not apply any effort in illegally extracting forest products. The players who choose effort levels 1–5 (5 is the maximum effort) are defectors. We used the following parameter values to match the scale of payoffs from forests in the communities where we conducted these experiments: a = 60, b = 5, and K = 20. The payoff matrix used in our study is given in Appendix Table A.1. In each round of the game, the payoff to each player depends on his own extraction effort and the extraction effort of other players in the game. This payoff is obtained by looking at the effort level in columns and the sum of all other players' effort levels in rows in the payoff matrix. The Nash equilibrium in this game is the effort level 5 by each player, which is obtained as the best response to the choice of all other players. However, the social optimum is obtained if all the players apply an effort 0, as it gives the maximum payoff to each one. The socially optimum payoff is, therefore, different from the Nash equilibrium payoff. It may not be realistically possible for the community members to apply 0 efforts, as these communities are dependent on forest resources for their subsistence needs. It is, therefore, necessary to find out the conditions under which the community members apply the least effort in exploiting the public forest resource.

2.3 Field Experimental Design

The JFM program is implemented by constituting Forest Protection Committees (FPC) for the management of different forests, normally located within the physical boundaries of a village. At the time of study, there were 1,734 FPCs in 26 districts of Gujarat and 914 FPCs in 12 districts of Himachal Pradesh (Govt. of India, Govt. of India (2005). We randomly selected three districts in Gujarat (Sabarkantha, Dahod, and Vadodra) and two districts in Himachal Pradesh (Shimla, and Mandi), where the JFM program has been implemented. In Gujarat, we selected 8 FPCs/district and in Himachal Pradesh 7 FPCs/district. Hence, field experiments were conducted in 24 villages of Gujarat and 14 villages of Himachal Pradesh. The game players were grouped in three resource and economic categories—rich (annual income more than Rs. 50,000), poor (annual income more than Rs. 25,000 but less than Rs. 50,000), and landless (annual income less than Rs. 25,000 and does not own any land in the village). The fourth user group consisted of women because women have the responsibility of fuelwood and other non-timber forest products collection in a household. Since, the game was designed for five players, we created the fifth group with mixed representation for the purpose of conducting the experiments, but we ignored the data from this group from our analysis. As stated earlier, the games were played by groups and not individuals. In the game, every village was represented by only one group each of rich, poor, landless, women, and mixed. Hence, the game was played by five groups in each village.

First, the game was played for the no communication situation. In this case, each player (group) allocated an effort in extracting forest products from the forest resource. The decision was made privately by the group, i.e., it was not told to the rest of the groups during or after the session. Once the groups made their decisions and wrote on the game form, they handed this to the game organizer, who added the total group efforts, which he announced publicly. Knowing this total, each group was able to calculate its payoff. Each individual group recorded its payoff for each round in the decision form. The game was repeated for three rounds. Second, the players (groups) were allowed to have face-to-face communication with the other groups before they took a decision in each round for the next 3 rounds.

Third, the organizer announced that each player (group) exerting an effort from 1 to 5 would be liable for light punishment. The punishments were a reduction in the payoff of the player by 10, 15, 20, 25, and 30 units for exerting an effort level of 1–5 respectively. The game was played with the light punishment possibility for 3 rounds. In real life, all illegal harvesters are not caught and punished, and therefore to catch the real life situation it was announced at the beginning of the game that in each round only one or two players (using the effort levels from 1 to 5) would be punished. These players were selected randomly. Finally, the game was repeated for 3 rounds with heavy punishment, which was also assigned at random, similar to the light punishment rounds. Under the heavy punishment, the payoff of each player was reduced by double the amount for each effort from 1 to 5.

2.4 Results of Field Experiments

The results of the field experiments confirm our original intuition that different forest user groups may have different preferences with respect to cooperation in forest management, and even the preferences of the same user group (rich, poor, landless, and women) may vary across communities. Some of these groups may have SR preferences while others may have OR preferences. ANOVA analysis of the data confirmed that the effort levels vary significantly from village to village and from treatment to treatment, and within a village the effort levels significantly vary among user groups and among treatments. Next, we present the analysis of our results in terms of the preferences of the four user groups and average effort levels applied by the four user groups.

2.4.1 Preference of the Four User Groups

The results of the field experiments for four treatments (no communication, communication, light punishment, and heavy punishment) are given in Table 2.1. In our analysis, a player means one user group from one community. Under the no communication treatment, the majority of players (user groups from different communities) used the effort levels ranging from 1 to 4 in both states, Gujarat and Himachal Pradesh. A small percentage of players in both states used zero effort level indicating their OR preferences; similarly, some players also expressed their SR (effort level 5) preferences. In Gujarat, the percentage of players with SR references was quite high among the poor (36 %), women (38 %), and landless (27 %) while among rich it was only 18 %. However, the percentage of players with SR preferences as compared to OR preference was higher among all four user groups in both states, but this difference was smaller in Himachal Pradesh than Gujarat. Communication had a very clear effect in both states: it increased the percentage of players with OR preferences, as compared to the situation of no

Table 2.1 User groups preference distribution expressed in percentage of players for the treatments of no communication, communication, light punishment and heavy punishment

State	Effort	Rich	Poor	Landless	Women
No communication					
Gujarat	0	15	8	7	8
	1–4	67	56	66	54
	5	18	36	27	38
Himachal Pradesh	0	9	3	12	0
	1–4	76	85	73	82
	5	15	12	15	18
With communication					
Gujarat	0	25	27	21	14
	1–4	50	46	44	62
	5	25	27	35	24
Himachal Pradesh	0	9	12	12	12
	1–4	88	79	79	85
	5	3	9	9	3
Light punishment					
Gujarat	0	59	54	27	53
	1–4	36	31	44	35
	5	5	15	29	12
Himachal Pradesh	0	22	11	25	19
	1–4	70	86	58	67
	5	8	3	17	14
Heavy punishment					
Gujarat	0	73	74	72	77
	1–4	22	15	20	16
	5	5	11	8	7
Himachal Pradesh	0	31	39	28	58
	14	43	55	55	39
	5	6	6	17	3

communication in both states for all the four categories—rich, poor, landless, and women. With respect to SR preferences, communication decreased the percentage of players in all four categories of user groups in Himachal Pradesh, but in Gujarat it had mixed effects.

The results of punishment clearly indicate that all four user groups care about punishment but the impacts of punishment are not even across the four categories of user groups. In the state of Gujarat, under light punishment conditions, the majority of the players expressed OR preferences; 59 % of rich, 54 % of poor, and 53 % of women user groups expressed OR preferences, and only in the landless category was the percentage of the players having SR preferences higher than the players having OR preferences. In the case of Himachal Pradesh also, light punishment increased the percentage of the players expressing OR preferences as compared to the case of no communication among all four categories of user groups, but this increase was not as large in Gujarat. Heavy punishment also had a greater impact in Gujarat than Himachal Pradesh. Under the heavy punishment treatment in Gujarat, more than 70 % of the players in all four categories of user groups expressed OR preferences, while in Himachal Pradesh, the percentage of players expressing OR preferences were 31 % in rich, 39 % in poor, 28 % in landless, and 38 % in women.

These results confirm that only a small percentage of players has the preferences of an idealized rational economic agent or so called SR preferences. The no communication treatment is representative of neo-classical economic assumptions and under this treatment only 18 % of the rich user groups expressed SR preferences, while this percentage was 36, 27, and 38 % among the poor, landless, and women, respectively. Under this treatment, the percentage of the players using zero effort (OR preferences) was not very high, but a very high proportion of the user groups used effort levels between 1 and 4. In fact, the players using the effort level of 1 were also quite concerned about the welfare of others. Similarly, the players using the effort level of 4 were more concerned about themselves than others. Hence, it may be useful if, instead of focusing only on the effort level of 0, which can be termed as a pure OR preference, and 5, which can be termed as a pure SR preference, we divide the effort levels into three categories: (1) effort levels of 0 and 1, labeled as "other-oriented" (OO) preferences; (2) effort levels of 4 and 5, labeled as "self-oriented" (SO) preferences; and (3) effort levels of 2 and 3, labeled as "mixed-oriented" (MO) preferences—mixed between self and other-oriented preferences. Using these three categories of preferences, preference distributions for four user groups and for four treatments are given in Figs. 2.1 and 2.2 for Gujarat and Himachal Pradesh, respectively.

Figure 2.1 shows that in Gujarat, in the case of no communication, the proportion of players (villages) having SO preferences is greater than the proportion of players having OO preferences as well as from the proportion of players having MO preferences for all four categories of user groups. Communication increases the proportion of players having OO preferences in all four categories of user groups, but in the case of landless and women user groups, the proportion of players having SO preferences is greater than the players having OO preferences. However, the impact of penalties is pronounced. In the case of the rich, poor, and landless user groups, the proportion of players with OO preferences is much higher than the proportion of players with SO preferences even with light punishment; with high punishment the proportion of players with SO preferences becomes very small among these three user groups. In the case of women, the impact of light punishment is not as high as the three other user groups, but heavy punishment has a pronounced impact even in the case of women.

The results from Himachal Pradesh are slightly different than the results from Gujarat. As shown in Fig. 2.2, in the no communication case, the proportion of the players with MO preferences was higher than the proportion of the players with SO preferences for all four user groups, and it was higher than the proportion of the players with OO preferences for all user groups except the user group of rich people. Communication reduced the proportion of the players with SO preferences and increased either the proportion of people with MO preferences (rich user

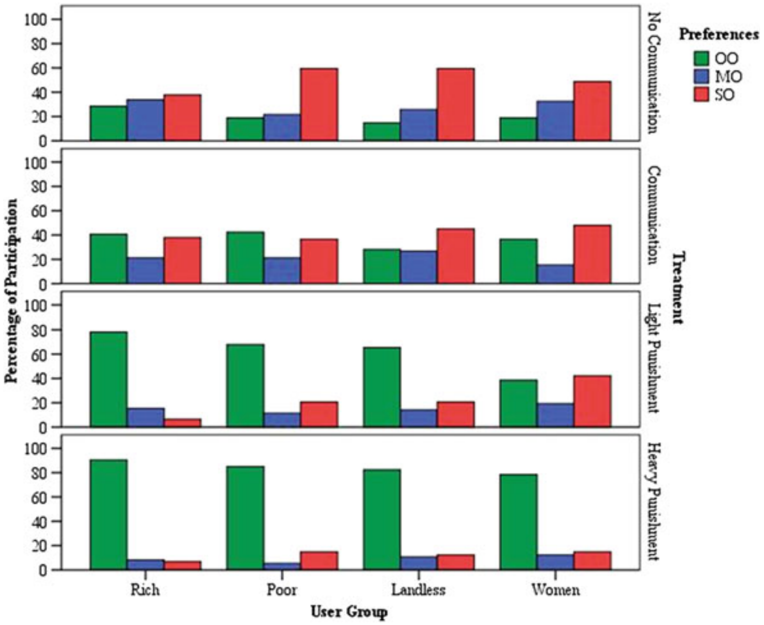


Fig. 2.1 Distribution of self-oriented, other-oriented, and mixed-oriented preferences among the four user groups under four treatments for Gujarat

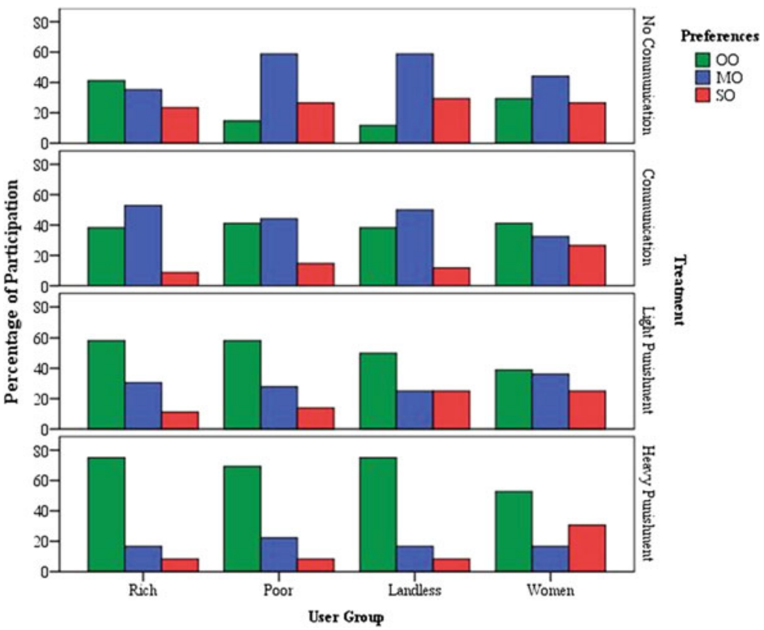


Fig. 2.2 Distribution of self-oriented, other-oriented, and mixed-oriented preferences among the four user groups under four treatments for Himachal Pradesh

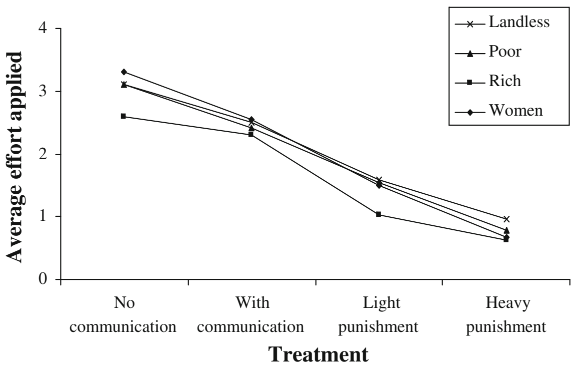
group) or with OO preferences (poor, landless, and women). Light punishment made the proportion of the players with OO preferences higher than the proportion of players with either SO or MO preferences for all the four user groups. Heavy punishment further enhanced the proportion of the players with OO preferences and decreased the proportion of players with MO and SO preferences for all the user groups.

2.4.2 Average Effort Levels of the Four User Groups

The average effort applied across both states by four user groups for four different treatments are shown in Fig. 2.3. The average effort is the maximum when there is no communication or fear of punishment, but even in this case the average effort applied by the four user groups varies between about 2.5 and 3.5 which is much below the effort that should be applied by the rational economic agent 5. In the case of no communication, more members tend to maximize their own private benefits from the resource without bothering about the negative externality imposed on others. Women, poor, and landless groups apply much higher effort than rich people in extracting forest products from forest resources. This is because women are primarily responsible for collecting fuelwood and some edible non-timber forest products to meet the subsistence needs of the family, and it shows higher dependence of poor and landless people on forest resources as compared to rich people.

The average effort applied by user groups decreases with communication. It was also noticed that the rich user group applied a lower average effort than other groups under the treatment of face-to-face communication. Although women and landless people reduced their efforts with communication, they continued to apply a higher average effort than rich and poor user groups in exploiting forest resources. The treatment of communication is similar to the situation where villagers sit together, form a Village Forest Protection Committee (FPC) and discuss the implications of over exploitation of the common forest resources. Although

Fig. 2.3 Average effort applied by community members for different treatments



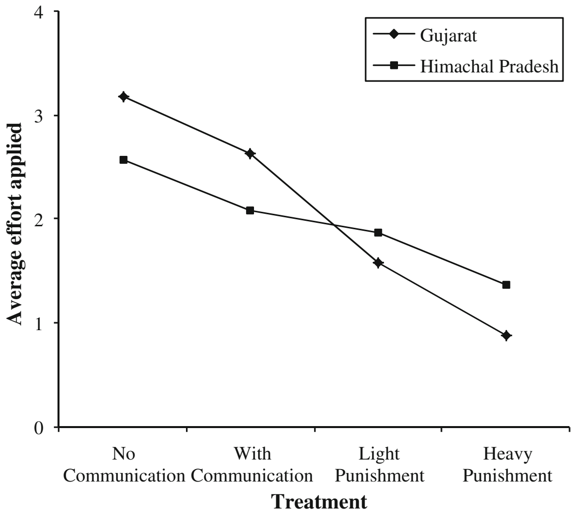


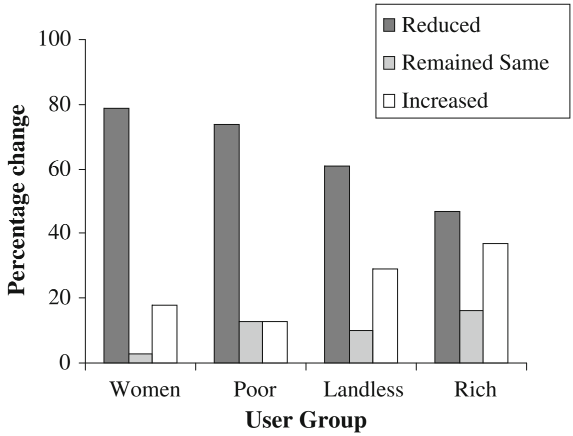
Fig. 2.4 Interstate comparison of average effort applied by community members for different treatments

individuals are still tempted to apply higher efforts to over exploitation of the resource, the committee tries to convince them about the long-term implications of their actions. Communication is based on the premise that individuals in a community always have some common shared values and norms. Communication uses these values and norms to establish trust and reciprocity, which are the key triggers of cooperation (Ostrom et al. 1994). The results of our experiment are consistent with most experimental evidence in public good and common property resource (CPR) lab and field experiments (Axelrod 1984; Ostrom 1990, 2000; Ostrom et al. 1994; Molinas 1998; Cardenas 2003).

Figure 2.4 shows a comparison of the interstate average effort. The comparison shows that the average effort applied by user groups in Gujarat is higher than in Himachal Pradesh without and with communication. However, the amount of effort applied by user groups is higher in Himachal Pradesh than Gujarat under the treatments of light and heavy punishment. This indicates that people are more law abiding because of the fear of punishment in Gujarat than Himachal Pradesh. The treatment of light punishment is similar to the situation where the FPC appoints watchmen for the protection and maintenance of the forest resource. The treatment of heavy punishment is similar to the situation where the watchmen are assisted by Forest Guards, who are generally much better equipped and trained to catch defectors. It was observed that all the individuals/groups further reduced their average efforts under these treatments as compared to the treatment of communication, indicating that people cooperate more under threat of punishment.

A comparison of the results of effort applied by different players for treatments of no communication and face-to-face communication between rounds indicates that a higher percentage of people reduced their effort after communication than the percentage of people who increased their effort or who did not change after communication (Fig. 2.5). It was also noticed that women outnumbered all other

Fig. 2.5 Percentage of players who changed average effort after communication



groups in reducing their effort after communication. They were able to better comprehend the long term consequences of depletion of forest resources and as such applied lower effort in exploiting these resources. These results show that face-to-face communication has a strong impact on mobilizing people to cooperate and preserve the common pool resources.

These results are similar to those of other researchers found in the experimental lab. Ostrom et al. (1994) studied the effects of costly punishment in a repetitive common pool resource game conducted in a lab. The authors found that there were material incentives for cooperation under the treatment of punishment, since the subjects could develop an individual rapport as they interacted repeatedly with the same group. Fehr and Gachter (2000) have shown that in the presence of punishment opportunities, there will be less free riding in the context of a public good experiment. The externally imposed regulation increases the private cost of over extraction and, therefore, reduces the incentives for free riding. However, there is an associated social cost of enforcing such regulations. Therefore, policy makers usually evaluate the capacity of enforcers to enforce the rules to achieve socially optimum behavior.

2.5 Conclusions

The results of a public good game, called as the JFM game, organized in 38 villages of Gujarat and Himachal Pradesh, India, were reported and analyzed in this chapter. Members of four user groups, rich, poor, landless, and women, participated in these games, and members of each group expressed their collective preferences of the group, and not their individual preferences. In fact, the insistence by the members of each user group to express the preferences of their respective groups itself indicated that these members are not rational economic agents. In addition, a consensus-based agreement on a group's preferences by all participating members of each group indicated that the members of all four user groups can develop informal institutions for mutual agreements and collaboration. These two observations from 38 villages of India are contrary to two key foundations of neo-classical economics – the rational economic agent and use of external formal institutions to force collaboration among different people.

The results of the games confirmed that a large percentage of players do not have the preferences of an idealized rational economic agent. In the case of the no communication treatment (a standard assumption of neo-classical economics), in aggregate forest user groups of Gujarat expressed non-self-regarding preferences in 70 % of cases while the user groups of Himachal Pradesh expressed SR preferences in 85 % of cases. These results confirm that there are some user groups with preferences similar to the rational economic agent, but their numbers are small as compared to the user groups with preferences different than the rational economic agent. Similarly, the proportion of the user groups who have pure other-regarding preferences (effort level 0) was also very small—about 10 % in Gujarat and 6 % in Himachal Pradesh. A large percentage of the user groups expressed preferences between the pure SR and pure OR, and this is a very important message to economic theorists and policy makers. Similarly, a substantial difference in the preferences of different user groups is also very important information for developing new economic theories as well as designing resource management policies and strategies.

Our results also supported the intuition that face-to-face communication may lead to a reduction in SR preferences as the percentage of the user groups who reduced their effort levels was much higher than the percentage of the user groups who increased their effort levels after communication. These results support some previous observations that face-to-face communication encourages cooperation among players. In real life, specifically in small places such as these villages in India, most of the people know each other and it is hard to imagine the situation where there is no communication between the different members of a village. Hence, in real life the percentage of the players who have pure SR preferences will be even smaller than the percentage we found in the case of no communication.

Our results for light and heavy punishment are also similar to those of other researchers under lab settings that self-governed solutions can emerge and succeed (Ostrom 2000). Although full cooperation cannot be achieved and maintained under any of the treatments, it is possible to reduce and limit the extraction effort of local communities so as to protect and sustainably manage these forest resources. The results from these experiments also support the idea that the tragedy of commons is not always the most likely outcome when a group has joint access to a resource, but rather that people cooperate in the use of common forest resources if they are ensured their subsistence needs will be met, and then communication and externally imposed regulations play a role to achieve cooperative behavior.

The results also suggest that it may not be possible to achieve a socially optimum extraction effort due to the dependence of community members on these

The results also suggest that it may not be possible to achieve a socially optimum extraction effort due to the dependence of community members on these natural resources for their daily subsistence needs. However, it is observed that cooperative behavior evolves under certain institutional conditions, which is better than Nash equilibrium based on self-regarding maximization of payoffs in a non-cooperative game. There is a need to pay careful attention to the role that preferences play in human behavior when designing institutions, and the needs of the individual groups to create trust and reciprocity to reduce the probability of free-riding by others. The government (forest managers) needs to build trust among community members by first ensuring their subsistence needs. This could be done by starting some income generation activities like forming self-help groups of women or providing employment to the landless for protection and maintenance of forests and engaging them in the collection of non-timber forest products so that they can become economically independent. In addition, the policy makers need to tackle defections with a heavy hand by equipping the enforcers better to deal with the defectors.

Appendix

Table A.1 Payoff matrix of the JFM game

		My extraction effort					
Their extraction effort		0	1	2	3	4	5
	0	90	89	92	95	97	100
	1	88	87	90	93	95	97
	2	86	85	88	91	93	95
	3	84	83	86	89	91	93
	4	82	81	84	87	89	91
	5	80	79	82	85	87	89
	6	78	77	80	83	85	87
	7	76	75	78	81	83	85
	8	74	73	76	79	81	83
	9	72	71	74	77	79	81
	10	70	69	72	75	77	79
	11	68	67	70	73	75	77
	12	66	65	68	71**	73	75
	13	64	63	66	69	71	73
	14	62	61	64	67	69	71
	15	60	59	62	65	67	69
	16	58	57	60	63	65	67
	17	56	55	58	61	63	65
	18	54	53	56	59	61	63
	19	52	51	54	57	59	61
	20	50	49	52	55	57	59

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Chapter 3
Complexity Theory and Forest Resource Economics

Martin Herbert Kijazi and Shashi Kant

Abstract A complex systems approach is used to test economic and moral values of actors, and their interactions with institutions towards sustainable forest management (SFM) in Mount Kilimanjaro, Tanzania. Chaos theory interpretations reveal that formal and informal organizations and institutions they promote serve as attractors that shape evolving preferences of actors—foresters, environmentalists, park authorities, entrepreneurs, and local communities—towards SFM. Diverse and dynamic preferences of heterogeneous actors including both self-interest and altruistic behaviors are observed; particularly, many economic and moral values oscillate in positive basin of attraction/optimization—indicating their complimentary nature. Thus, the economic agents presented in this analysis behave in a manner of the so called 'socially-rational agent', rather than self-interest maximizing agents of the Faustmann's model. Institutionally, there are informal advocacy coalitions with actors from different formal work organizations, but with shared values towards SFM. This is coupled with strong positive valuation of co-operative (participatory and collaborative) arrangements of SFM vis-à-vis conventional centralized forest management. While SFM values limit cycles oscillate in more stable and desirable basins of attraction, institutions limit cycles show more chaos. The latter outcome suggests that continued SFM institutional reforms, rather that mere value sensitization, are critical ingredients towards SFM.

M. H. Kijazi (✉) · S. Kant
Faculty of Forestry, University of Toronto, 33 Willcocks St,
Toronto, ON M5S 3B3, Canada
e-mail: tini.herbert@utoronto.ca

S. Kant
e-mail: shashi.kant@utoronto.ca

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3.1 Introduction

Economics of 'sustainable forestry' has a long history since the classic land rent theory based on maximizing soil expectation value of perpetual timber rotations (Faustmann 1849) and optimum financial rotation (Pressler 1860). According to the Faustmann's land rent-theory, it is optimal to harvest a stand when the rate of change of its value with respect to time is equal to the interest on the value of the standing trees plus interest on the value of the forestland (Tahvonen and Viitala 2006). This outcome, however, requires perfect markets for capital, timber, and other inputs; no uncertainty; and forest owners without environmental preferences (Samuelson 1976; Johnson and Löfgren 1985). While classical land rent theory is based on timber only, current forest valuation and management require incorporation of diverse values provided by forests (Turner et al. 2003). Yet, the foundation of the current forest economic thought on neo-classical economics retains many land rent theory features of efficiency and control. For example, the assumptions of fixed tastes and homogeneous, super-rational, independent agents competing to maximize their self-interests are retained (Colander 2005; Kant 2005). The resulting 'single equilibrium' is, under the right conditions, supposed to also maximize social welfare. These features render the classical land rent theory inadequate in addressing sustainable forest management (SFM), which is characterized by multiple agents (in present and future generations) with diverse and dynamic economic, social and environmental preferences (Kant and Lee 2004; Kijazi and Kant 2010).

Analytically, the above features of the land rent theory and neo-classical valuations fit neatly into linear algebra and calculus framework, which underlies most analytical tools of what Colander (2005) calls the "efficiency story". However, SFM features do not fit-well with the efficiency story. Rather, SFM is characterized by complexity story, which views change (e.g. progress towards SFM) as an evolutionary process occurring concurrently at multiple levels (Colander 2005). Accordingly, policy is affecting mutually-dependent variables some of which are gradually moving while others are rapidly moving. Thus, rather than solely searching for optima, like in the case of land rent theory, SFM analyst need to look for early indicators of switch points that will fundamentally change the nature of the system (ibid.). Also, in contrast to the efficiency story, economics of SFM are characterized by requirements for co-operative arrangements, featuring both self-interest and altruistic behaviors of agents (Kant 2005; Kijazi and Kant 2010). This entails complementarities of economic and moral values; plus, diverse and dynamic preferences of heterogeneous agents (Colander 2005; Kant 2005). Non-linear systems approaches that consider complex interactions between social, economic and natural systems are more appropriate for such features (Kijazi 2007). Thus, complexity theory, rather than the land rent theory, may be more suited to the analysis of SFM matrix involving heterogeneous agents with diverse preferences.

In this chapter, we use complexity theory to analyze a SFM forest-actor matrix including economic, social, and environmental values, and we examine early indicators of switch points towards SFM in Mount Kilimanjaro eco-systems of Tanzania. By using complex system model, we are not concerned about equilibrium. Our interest is basins of attractions that govern behaviours of the forest-actors and their interactions with their eco-system towards SFM. Thus, in our analysis nonlinearities are accepted, and phase transition jumps as the system evolves are anticipated (Priesmeyer 1992; Dent 1994; Dooley and Van de Van 1999). We analyze SFM from the forest economics perspective, within a complex system of interaction of multiple actors, modeling heterogeneous preferences of these actors towards SFM. In this context, the following are our premises. First, the proto-typical rational choice of the so called “Homo economicus” or the “rational economic man” (Pareto 1906), also termed “Chicago man” (McFadden 1999; Kant 2005) and who is implied in the Faustmann land rent theory, is difficult or impossible to specify. Rather, we anticipate that multiple levels of the system, not only the individual, are optimizing. The anticipated multiple levels of optimization include individual actors and coalitions of actors within their formal and informal forest-related organizations, namely stakeholder-groups and advocacy coalitions respectively (Kijazi 2007). By analogy, the individual is the result of lower level optimization at the atomic level, but the individual is a component of higher (elemental to compound) systems, e.g. stakeholder-groups, which are themselves optimizing, and competing for existence in the higher level. Second, consistent with rational-institutional choice rules (Ostrom 1990) we presume that organizations promote values and institutions which shape individuals preferences at this higher level of optimization. Third, we apply the principle of complementarity, as per Kant (2003a, b) and Khan (2005), by including variables in the matrix that would allow forest-actors to exercise both selfish and altruistic behaviours; economic and moral values; and to satisfy their lower level needs as well as higher level needs. Fourth, in the complex forest-actors-eco-system, all components including actors and their coalitions plus the eco-system are coevolving together—this is the higher cosmic-level optimization. Fifth, given the foregoing premise, borrowing from Colander (2005), even if one can specify what one means by rational choice non-contextually, the systemic forces rewarding “rational choice” are often weaker than they are in simple systems. Sixth, unlike in neo-classical economic theory, the analysis does not anticipate or project a predetermined equilibrium that must finally be reached if the system is left to its own devices. Rather, in the long-term, the complexity modeling is charted around the dynamic process through which one basin is reached temporarily, but other forces are building up to push it into another basin—akin to cosmic evolution. Seven, at a given time, then, sustainability means keeping within the existing, desirable basin of attraction, or moving into a more desirable one, but not going to another that is considered less desirable (Colander 2005; Musselwhite and Herath 2007).

In the context of the foregoing premises, the complexity modeling of the behaviors of forest stakeholders in Mount Kilimanjaro, Tanzania, include both their value (substantive) and institutional (procedural) preferences related to SFM. Specifically, we examine purposeful behaviors; informed self (or collective) choices and interests; and sustainability of the observed behaviors based on the stability of their current limit cycles. Stakeholders surveyed include forest authorities, park authorities, environmentalists, private estates and local communities. Then, we examine the role of formal and informal organizations, which create attractors that govern the dynamic choices/interests and interactions of stakeholders, specifically, the role of formal employment organizations (as stakeholder groups) and that of informal advocacy coalitions of individuals from different formal organizations but who share values, beliefs and purposeful activism towards SFM.

Next, in Sect. 3.2, we review the theoretical aspects of SFM, economic analysis, and complexity theory related to this study. In Sect. 3.3, we detail methodological aspects of empirical study. Results of the empirical study are presented in Sect. 3.4. The results are discussed in Sect. 3.5, followed by conclusions in Sect. 3.6.

3.2 Forest Sustainability, Economics, and Complexity

Sustainability has been embedded in forest economics for nearly last two hundred years, but the meaning of sustainability has evolved. Intellectual lineage of sustainability in forestry can be traced to the contributions of Pfeil (1822), Hundeshagen (1828), König (1864), Pressler (1860), but most particularly Faustmann (1849) illustrious soil expectation value formula. Mathematical optimization used to determine the best forest management solution, through determination of the land expectation value, corresponds with the principles of the neo-classical investment theory (Möhring 2001). However, as early as the 19th century, it was recognized that the land rent theory conflicted with the principle of maximum sustained yield timber management. By requiring reduction of usual rotations and stocking density and assuming that forestry investments start as an investment on bare land, the land rent theory also conflicted with the practical needs of foresters to manage the already existing forests using forester's rotation (Borggreve 1878; Möhring 2001). Regarding this tension, Möhring (2001) noted that Borggreve wrote: "The question is whether to liquidate the forests inventory or not…" (p. IX), and then he claimed "The forester's task in the first place is to maintain the forest and not to destroy or reduce it" (p. XI). The antithesis of the land rent theory, the so-called theory of the highest revenue that followed it was also criticized for focusing on the utility of wood production only, at the exclusion of non-timber forest products such as nature conservation, watershed protection, recreation, etc., which are also important to society (Möhring 2001). Thus, in Prussia, Hagen (1867) declared so-called 'golden words', which would not adhere to the principle of highest financial returns; rather, the state of Prussia was 'obligated to manage its forests to maintain an equal flow of multiple products for general welfare and future generations' (Möhring 2001).

The foregoing observations attest to the centuries-old-conflict between purely economic thinking vis-à-vis ecological limitations and social expectations. The conflict also indicates early recognitions of the over-simplifying nature of, albeit analytically elegant, economic models that are divorced from the complexity that exists in human and ecological systems. Yet, such neo-classical economic models founded on efficiency, control, and single equilibrium premises, have remained dominant in forest economics particularly under the sustained yield timber management era (SYTM) (Kant 2003a, b, 2005).

Forest valuation challenges in SFM have increasingly revealed that the SYTM-era models of forest valuation are incapable of delivering solutions useful to many forest economic decision problems under SFM (Kant and Lee 2004; Kangas et al. 2006; Kijazi and Kant 2010, 2011). This is particularly so because SFM has the goal of transforming forest management from SYTM to forest ecosystem management and from forest management by exclusion of user groups to management by inclusion of user groups (Kant and Lee 2004). Notably Forest economists have responded to SFM by the use of direct or indirect valuation techniques for non-marketed goods and services, so that these values can be made comparable with the values of traditional wood products (e.g. Lockwood et al. 1993; James 1994; Bateman and Lovett 2000; Bostedt and Mattsson 2006). However, numerous problems exist with the application of market-based methods for valuation of environmental attributes in general (Sen 1995) and forest valuation in particular (Kant 2003a, b; Kant and Lee 2004; Kijazi and Kant 2010, 2011). Primarily, the 'willingness to pay' foundation of these market-centered valuations does not provide room for all (economic and moral) socially defined forest attributes, or social states, to which individuals as citizens would attach importance, and which are critical for public discussions or decisions about SFM (Kant and Lee 2004; Kijazi and Kant 2010, 2011). These limitations are compounded by what Polanyi (1944, 2001) calls the fallacy of 'commodity fiction' of *laissez faire* economics, which when applied to nature and human societies results in drawing arbitrary boundaries around objects, thereby converting systems into disaggregated and discrete units, which are treated as separable without functional relationship between them. This ignores the complex interactions within human societies and between human societies and nature, which are critical for understanding economic foundations of SFM.

In responses to these limitations of neo-classical economic approaches, some economists have suggested the use of multiple criteria decision analysis (Bare and Mendoza 1992; Gong 1992; Kangas 1993; Liu and Davis 1995) and social choice approaches (Kant and Lee 2004; Kangas et al. 2006; Kijazi and Kant 2010) to SFM. Additionally, contributions from the other so called 'heterodox economics', including post-Keynesian economics, evolutionary economics, ecological economics, behavioral economics, experimental economics, and agent-based modeling (Kant and Berry 2005) are also very useful for economic analysis of SFM. Colander (2005) provided a strong theoretical justification for the use of complexity theory to analyze such complex matrix of SFM. This study is an empirical investigation in this direction.

In the context of sustainable development, SFM means managing forests to meet the needs of the present without compromising the ability of future generations to meet their own needs. Economically, this demands elements of altruistic and cooperative behavior among social agents in contrast to the self-interest-maximizing rational agent of neo-classical economics guided by the "either-or" principle (Kant 2003a). Thus, in this study, in the context of "both-and" principle (Kant 2005), we use complexity theory model to capture dualistic nature of individual's behavior; i.e. both individualistic as well as altruistic and/or commitment orientations related to SFM values and institutions. Also, we discuss the results of our analysis on the basis of Kant's (2003a) proposed four sub-principles of SFM economics: existence, relativity, uncertainty, and complementarity, alongside premises of the complexity theory. This integration is supported by Kant (2005) observation that the complexity story of sustainability (Colander 2005) is consistent with Kant (2003a, 2005) economic principles of SFM. To achieve this integration, we place the two frameworks within a higher unifying 'principle of interdependence', which we believe is implied in both. Colander identifies the economics of SFM as part of a broader trend within economics, that he defines as a switching from the efficiency and control story to the complexity and muddling through story. The latter is a dynamic and evolutionary story, not characterized by a single equilibrium, but by basins of attractions. Sustainability, then, means remaining either in the existing basin of attraction or going to a more desirable basin but avoiding less desirable basins (Colander 2005). In this study, through the use of iconographic mapping, a common tool in complexity analysis, we examine basins of attraction that govern evolution of preferences of forest-agents in Mount Kilimanjaro towards SFM.

3.2.1 Analyzing Chaos in Complex Systems

Whereas analyzing complexity in economics of SFM is in infancy, major advancements in complexity theory have occurred in other fields, from which this review and subsequent analysis borrow. Our analysis, however, is limited to one branch of complexity theory, termed "chaos theory". Chaos theory describes the long-term behavior of a non-linear and dynamic system characterized by a great deal of irregularity at the micro-level but rather deterministic regularity at the macro-level (Kiel and Elliott 1996; Staveren 1999). Chaos theory is used to show such pattern of relationship between variables in a non-stochastic fashion (ibid.). There are three basic phenomenon associated with 'chaos': (1) the butterfly effect; (2) strange attractors; and (3) bifurcation. The butterfly effect associates chaotic systems with sensitivity to initial conditions, whereby, small variations of the initial condition may produce large variations in the long-term system behavior (Strogatz 2000; Devaney 2003). An attractor is an underlying order in a non-linear system, where the mathematical points describing the system's behavior create pattern and structure (Kiel and Elliott 1996; Staveren 1999). Bifurcation is a process whereby the outcome splits into two; thus, linear continuity of nonlinear system's behavior is interrupted by dramatic change of relationship between variables (Gleick 1998). Our study is an examination of attractors or bifurcation patterns in a SFM value and institutional matrix, testing whether geometric representation of numerical data, describing the Kilimanjaro SFM regime, creates unique shapes of order relevant for SFM.

Specifically, our study examines presence of social-organizations, including SFM values and institutional variables, as basins of attraction, which govern stakeholder preferences and interests, or create bifurcation patterns that shape forest stakeholders' preferences in the dynamic social-ecological system. This is achieved through geometric representation of numeric data representing stakeholders' value and institutional preferences; then, by examining how the current patterns of forest stakeholders' preferences have been influenced by institutional-historicity of stakeholders, as discussed next.

3.2.2 Complexity, Historicity and Spatial-Temporal Dynamism

Understanding a complex system requires understanding the historical processes and interactions that led to the development of consistent patterns of behavior across time. Organization of human societies reflects dominant societal, historically formed self-understandings, and organizations reproduce the beliefs, values and interests as well as institutional practices of the society in which they are embedded, and in so doing they help perpetuate them (Tsoukas 1998). Economically, this has been empirically supported in historical analysis of sustainability of forests and other common-pool resources (e.g. Ostrom 1990; Gibson and Koontz 1998; Ostrom et al. 2002) and in economic rationality of individuals in general (Sen 2002). In complexity analysis of social systems, if the main interest is to establish temporal pattern of behavior, quantitative recording of longitudinal data (time-series and panel data) are indispensable. For spatial analysis, though, even cross-sectional data, as presented in this analysis, is adequate. But such analysis must be viewed also in relation to temporal nature of historical data captured in a cross-sectional study. According to Grengesen and Sailer (1993), at the abstract level, complex/chaotic systems share three important properties: (1) The system's state vector z_t at time t—i.e. cross-sectional profile; (2) An embedded environment's state vector $u_{t;}$ (3) The state of the system at time $t + 1$ is a function of the system state z_t and the environment state u_t at time t. Given that time and space are central aspects of chaos analysis, some social studies have applied time-series data (e.g. Frank and Stengos 1988; Combs et al. 1994). However, whereas limit cycles in chaos analysis typically report the evolving dynamic response of a system over time, they are not limited to time-dependent responses (Priesmeyer 1992). Hence, using cross-sectional data, as we do in this study, time could be replaced by profile of respondent attributes in a three-dimensional geometric depiction of system dynamics: the first two depicting observed behavior as influenced by the third dimension, which represents respondent attributes (Dent 1994). An important aspect of complexity, however, remains valid: a given variable (or variables) affect (s) another (or others) in a non-linear, discontinuous, or even circular fashion. The influential variables are also affected by the dependent variable due to feedback between variables.

This leads to a question that can the role of time be totally dispensed of? To answer this, two other central questions need answering: does time, t, (above) represent an instant or duration? What role does t, per se, play apart from the state vector z_t and its environmental state vector u_t? Kijazi (2007) illustrated that time, t, alone, has no role independent of the system's state vector z_t and its environmental state vector u_t. Hence, it is more meaningful to speak of spatial–temporal influences as one unified aspect of reality, where time is only one dimension of space. Then, within a given space–time environment, the time t required to shape system behavior at t + 1 will depend on the context of state vector z_t of the system and its environmental state vector $u_{t.}$ For example, in making leavened dough, an instant yeasting at time t (in seconds), is sufficient to influence the evolution and the state of the dough at any time t + 1. In contrast, the time, t, for the formation of dominant human choices and interests (e.g. related to SFM in this study) in a given society, is likely to be a duration, possibly many years required to establish institutions and social norms and values that shape these choices and interests, by experiences and feedbacks; in this case time, t, represent a duration (or history) rather than an instant. Such duration of experiences and feedbacks defines the underlying historicity.

In this study, therefore, as a time-modulator variable we use historicity of forest actors; i.e. their historical profile of SFM related organizational affiliations and activism—which approximates their system state z_t and environmental state vector u_t. In one unified dimension. The latter is then related to current pattern of actors' SFM preferences (system behavior at time t + 1). By analogy, our analysis is akin to a physician who prescribes treatment by diagnosis of patient's current symptoms (systems behaviour) in the context of patient's historical profile of ailment (state and environmental vector). Moreover, we contend that such current preferences (i.e. system behavior at time t + 1)—corresponding with specific values and institutions—though recorded in cross-sectional data also have temporal basis. This can be understood in the context of the "associative memory" notion of "social cognition and attitude theory", where current cognitions and value judgments are results of cumulative experiences, which may be activated on presentation of specific information of stimuli (Eiser 1997). This relates also to Hopfield's (1982) views of content-addressable memory, which entails accessing an attitude from memory in response to some priming stimulus or contextual cue—that is, "calling it into conscious experience". So, an attitude or value judgment that is strongly reinforced or associated with contextual cues function as a powerful attractor (Eiser 1997). In this context, based on the content of the Tanzania SFM policy (GOT 1998, 2002) we prepared evaluative survey questions.

The questions were used as stimuli, or contextual cues, for eliciting SFM preferences of respondents/forest actors in Kilimanjaro. But such currently stated preferences, and their corresponding basins of attraction, have an underlying history. They have arisen overtime and in the given historical context, they tend to converge to the current state. In complexity theory language, our interest is to examine how sustainable (i.e. stable and/or desirable) or unsustainable (i.e. unstable and/or undesirable) their limit cycles are.

3.3 Empirical Investigation

3.3.1 The Study Area

Mount Kilimanjaro is located 300 km south of the equator, in Tanzania, and it is the highest mountain in Africa reaching 5,895 m above sea level at its highest point. Mt. Kilimanjaro is the oldest protected area in Africa by contemporary state law, and was first declared as a game reserve by the German colonial government in the early part of the 20th century. The area was further gazetted as a forest reserve in 1921. The area above the main forest line (2,700 m) was reclassified in 1973 by the Tanzanian Government to form a National Park, covering 75,353 ha, surrounded by a Forest Reserve of 107,828 ha. Mt. Kilimanjaro National Park was inscribed on the World Heritage list in 1987 (Lambrechts et al. 2002). The mountain is a source of diverse values including : (1) domestic and industrial water; (2) an estimated 2,500 plant species and 140 mammal species (Lambrechts et al. 2002); (3) recreation values for domestic and foreign recreationists (Loibooki Loibooki 2002); (4) timber, honey and other bee products, fuel wood, nuts, fruits, root crops, seeds, poles for construction etc. The main stakeholder groups include local communities, Non-governmental Organizations (NGOs), government agencies, private sectors, local and global conservation organizations and other user groups (MNRT 2003).

3.3.2 Analytical Framework

The empirical analysis uses three-dimensional iconographic plots to examine the system dynamics from survey responses relating to values and institutional aspects of SFM. Stakeholders' scores over values or institutional attributes of SFM are plotted as X and Y (first and second) dimensions, while respondent data describing his/her historical profile are used to replace the time modulator (third dimension). The profiling data in this research include formal (work-related) organizational affiliations and informal organizations (advocacy coalitions, which will be described shortly). Questions relating to respondent's preferences are weighted by respondents on a five-point Likert scale (Likert 1932). The scale ranges from strongly disagree (−2) to strongly agree (+2) with the posed SFM value or institutional statement, where undecided/uncertain answers are given a value of zero. Each survey question is specifically delineated to provide a separate axis of the "phase space", in complexity theory language, providing four main basins of attraction corresponding with the four quadrants of two-dimension X–Y plot (two basins for positive scores and two basins for negative scores). But within each basin, there are low and higher planes of optimization corresponding with the stakeholders' scores (e.g. +0.5 and +1 are lower levels of optimization than +2 in, albeit, the same positive basin of attraction.)

We hypothesized that formal and informal organizations, including values and institutions they promote, are quite important modulators of individual and social behavior, hence individual and collective choices. Because values and institutions they promote bear a history/time dimension, formal and informal organizational profiles were used directly to replace the time modulator in their own right so as to show patterns of individual and collective choices as influenced by institutional arrangements that have unfolded in the course of history. In this case we can think of a scale (level) of belonging of a respondent to a particular profile of organizations/institutional-historicity. Two types of organizations are considered: formal employment/work organization and informal 'advocacy coalitions'. The latter is consistent with the notion and premises of the "advocacy coalition framework (ACF)" (Sabatier 1993; Elliot and Schlaepfer 2001). The ACF corresponds with the institutional rational choice (Ostrom 1990) on the notion that institutional rules affect individual behavior, including their choices. The ACF, however, views these rules as a result of strategies and activities of advocacy coalitions.

3.3.3 Questionnaire Surveys

The field micro-survey was conducted in March—April, 2005. Prior to questionnaire surveys, a combination of review of policy documents and formal interviews with key representatives of different stakeholder groups were done: the objective was to appraise history of policy and institutional arrangements governing the management of forest resources in Mount Kilimanjaro before and after official adoption of SFM policy (GOT 1998, 2002). Then, a total of 133 respondents were questionnaire-surveyed (see survey procedure, next section). The questionnaire was divided into two sections. The first section contains respondents' historical profile data used as time modulator replacement: (a) formal occupation/profession, and (b) informal organizational/institutional affiliations and activism within the last decade. The second section, which is intended to elicit stakeholder preferences, provides overall preference scales and relates these scales to preferences that are specific to SFM values (substantive outcomes) and institutional/procedural aspects of SFM prescribed by the Tanzanian forest policy (GOT 1998).

3.3.4 Sampling Procedure

The study used stratified and cluster sampling. The following steps were followed: (a) deliberate choice of strata based on an auxiliary variable “organizational affiliation”, leading into local community stratum, NGOs stratum, entrepreneurs (coffee estate) stratum, environmental agencies stratum, park authority stratum, and forest authority stratum; (b) clustering, which involved semi-random selection (based on accessibility) of ‘representative villages’ among villages that constitute the ‘local community’ stratum; (c) choice of participants within a given strata or cluster, by systematic random sampling in order to ensure reliable inferences. The first sampling point (respondent) was randomly selected in the list of members of a stratum or cluster, e.g. a list of adult villagers (>18 years old) from village register, followed by selection of every next kth member from the first sampling point where k, the sampling interval, is calculated as: k = population of adult villagers registered (N)/sample size required per village (n). The similar approach was used for other stakeholder groups. Conservation NGO and coffee estate surveyed were those within, or in close proximity to, the sampling transect determined by selection of representative villages (as described above). Park and forest authorities were deliberately chosen by virtue of their active involvement in the management of Mount Kilimanjaro forests.

The 133 respondents were surveyed based on a trade-off between statistical reliability versus resource constraints for obtaining larger sample size in such remote areas. To determine the number of respondents required for each stakeholder group, the proportionate allocation criterion was used qualitatively for guidance where larger sampling fractions were allocated to the strata with larger proportion of the total population and vice versa. Hence largest number of respondents (about 70 %) was obtained from the local community. Of the remaining 30 %, the Forest authorities and NGOs were assigned the larger proportions: about 9 % each (the former due to high proportion of its agents involved in forest decisions, and the later due to expected high variance—as the NGOs were observed to have workers with diverse backgrounds varying from local to international representatives). The private estates and park authorities were assigned smallest proportions of the total sample (6 % each) due to their actual smallest numbers of agents involved in current forest management decision-making in practice. A list of sampled stakeholder groups and sampled members per stakeholder groups is provided in Table 3.1.

3.3.5 Profiling Questions

Formal occupational organizations considered were those directly relevant to this research including: (a) National Park; (b) Forest Agency; (c) Coffee Estate; (d) Conservation NGO; and (e) Local Agrarian Economy. Advocacy coalitions

Table 3.1 Stakeholders surveyed in Mount Kilimanjaro

Stakeholder group	Agencies	Sample size
Local community	*Villages:* Lyasongoro, Nanjara, Mbomai, Kikelelwa, Rongai, Kamwanga, Kitendeni, Irkaswa, Lerang'wa, Olmolog, Londross, Ngaronyi, Foo, Mweka	93
Environmental groups	Himo environmental management trust fund (HEM);community management of protected areas conservation project and; Mweka community-based environmental organization	12
Forest authorities	Catchment forest office headquarters, Dar es Salaam; South Kilimanjaro catchment forest office, Moshi; Kilimanjaro regional forest office, Moshi; Hai district forest office	12
Park authorities	Tanzania national parks (TANAPA), Arusha; Kilimanjaro national parks (KINAPA) headquarters, Marangu; KINAPA outposts—Mweka, Rongai, Ngaronyi	8
Private (coffee) estates	Tchibo estate, Simba farm, Mountainside farm	8
Total		133

were determined by clustering of individuals from diverse organizations based on shared activism as determined by structured and open-ended questions requiring respondents to express their past and current non-job activities related to environmental activism, social justice activism, and community development activism, including collaboration with organizations undertaking such activities, during the decade preceding the survey. An environmental activist coalition, for instance, consisted of individuals that, in their historical profile, have self proclaimed to be environmental activists and also indicated evidence of environmental activities such as engagement with local environmental committees, tree planting, environmental campaigning, etc. Nine such coalitions were determined: (a) environmental activist coalition—as just described; (b) environmentally oriented coalition—self proclaimed support for environmental issues but no further evidence of activism in the profile; (c) environmental/resource committee coalition—involved in local environmental and natural resource committee but neither self proclaimed to be environmental activist, nor evidenced so in personal profile; (d) social justice activist coalition—self proclamation and/or other evidence of social justice activities; (e) community development activist coalition—self proclamation and/or other evidence of community development activities; (f) estate-economy coalition—estate workers without off-job activism; (g) forestry coalition—forest workers without off-job activism; (h) park coalition—park workers without off-job activism; and (i) local community coalition—local community residents without activism outside regular agrarian activities. Such clustering indicated that the environmental, social justice and community development coalitions have members from park, forest, and environmental organizations and local agrarians, thus, confirming the validity of the advocacy coalition framework (*op cit*).

3.3.6 Stakeholder Preferences of Values and Institutions

The second section of the questionnaire had two sub-sections. The first sub-section consisted of questions about stakeholder preferences regarding utilization and conservation of forests on Mount Kilimanjaro, specifying proposed substantive outcomes of forest management interventions e.g. timber harvesting in plantation forests and native forests; personal welfare values, societal welfare values, bequest values, etc. Thus, this section also required preferences for a wide range of SFM propositions including both self-interest and economic versus altruistic and moral values. The second sub-section required respondents to express institutional preferences necessary for SFM. For this purpose we provide a mix of formal and informal, as well as endogenous and exogenous institutions considered necessary to achieve SFM. By formal institutions, we mean those prescribed by law, e.g. forest governance regimes currently prescribed by the national forest policy (GOT 1998) and the forest act (GOT 2002), viz., state-controlled centralized governance, collaborative (joint-management) regime, and community-based/participatory regime. Formal institutions also include such aspects as forest-related rights and obligations endowed or obligated upon different actors by law (e.g. rights of local communities to extract products from forest buffer zones, and obligations to manage such forests, etc.). Informal institutions include forest governance rules and norms not necessarily defined by official law, but considered necessary to achieve SFM—e.g. trust, social norms, and networks of communications between different actors. We define endogenous institutions as rules and norms that are endowed from (and operate) within an organization—e.g. trust, social norms and networks just described. On the other hand, we define exogenous institutions as those that have to be guaranteed or imposed by an external agent—e.g. actors rights defined by law, financial guarantees to manage forests provided by the state to agencies entrusted with/or obligated to manage forests. Thus, our two classifications—formal and informal, endogenous and exogenous—are not mutually exclusive as some variables may fit both classifications. But the inclusion of both provides a more comprehensive framework for analysis and interpretation of the results. A list of value and institutional variables presented to respondents is summarized in Table 3.2.

3.3.7 Data Analysis and Interpretation

A description of limit cycles and other terminology used is summarized in Table 3.3 to enhance readers' comprehension. The time modulator replacement, i.e. respondent historical profile question, including formal organizational affiliation or informal advocacy coalition, was charted as the independent variable (third dimension), with responses to institutional and substantive choices of stakeholders related to SFM (i.e. actors' preferences) as dependant variables (first and second

Table 3.2 Variables used in the analysis and their contextual descriptions

	Values	Descriptions
1	Logging native species	Logging high value native timber species is necessary for local, regional and national economic well-being
2	Logging plantation species	Logging industrial plantation species is necessary for local, regional and national economic well-being
3	Local community use values	Local community regulated access to subsistence uses of forests is necessary
4	Conservation values	Conservation of biodiversity and eco-system services e.g. hydrological/water catchment values are necessary
5	Cultural and heritage values	Forest values necessary for sustaining local to national culture, traditions and customs
6	Option values	Differed uses of forests for future needs of present generations are important for SFM
7	Bequest values	Forests bequeathed to future generations to meet their needs
8	Existence values	Forests left to exist for their own goodness irrespective of human use
9	Personal values	Forests are necessary for actor's personal and/or household welfare
10	Organizational values	Forests are necessary for actor's organization's welfare
11	Societal values	Forests are necessary for societal (regional and national) welfare
	Institutions	*Descriptions*
1	Trust, social norms and communication networks	Actor's organization/community has adequate informal institutional rules necessary to monitor and reward or sanction individual behavior towards SFM
2	SFM Commitments	Actor's organization SFM roles, duties, objectives and obligations are clear
3	Stewardship	Actor's organization is taking actions towards SFM
4	Legitimacy	Actor's organization has institutional, legal, and customary authority to influence SFM decisions
5	Capacity	Actor's organization has financial and physical infrastructure and capabilities to effect SFM
6	Rights	Forest-related rights of the actor are clearly defined
7	Participatory/community-based	Local communities and other local stakeholder should play a greater decision-making and implementation SFM role as custodians of forests
8	Collaborative/joint forest management	Need to engage multi-stakeholder collaboration coordinated by a central agency
9	Centralized state bureaucracy	Centralized decision-making and law enforcement by a central/state agency should continue

dimensions). For each stakeholder group or advocacy coalition, mean values were calculated for each response according to the response chosen in each segment of the time modulator replacement question. The minimum and maximum means

Table 3.3 The key chaos theory terminologies and metaphors used in the study

Attractor	An underlying pattern of behavior that exists because of the inherent structural characteristics
Bifurcation	A branch point causing a different level of complexity. At bifurcation points, the system may become more or less complex
Limit cycle	The plotting and connecting of sequential observations on a phase plane
Period	A measure of the complexity, or amount of chaos or order between certain variables
Period 1 limit cycle	The least degree of chaos. Both variables always move together in one direction
Period 2 limit cycle	When only two quadrants are visited out of every four data points
Period 4 limit cycle	When all four quadrants are cycled before a quadrant is revisited
Period 8 limit cycle	Any limit cycle which is more complex than period 4
Phase space	The phase space is used to map the coordinates of the variables defining the behavior of the system in a multi-dimensional plot

This usage is consonant with typical usage in chaos analysis in social sciences using analytical approaches similar to this study (See for example Priesmeyer 1992; Dent 1994; Musselwhite and Herath 2004)

possible are then −2 and +2, respectively, for any response, which corresponds with the highest level of preference (or highest plane of optimization) in any basin of attraction/quadrant. When plotted, the cross-axis is zero.

In the time variables of qualitative nature, e.g. organizational historicity, natural ordering of responses is non-existent. Thus, we resort to post-analysis ordering, following a simple rule of thumb: after analysis the responses are ordered in way that would obtain the most parsimonious limit cycle; the data is thus plotted starting with the coordinate with the smallest Cartesian/Euclidean distance to the cross-axis, (say a = x1, y1) following with the coordinate with the second smallest Cartesian distance to the cross-axis, (say b = x2, y2), and so on. In addition to providing a standard approach, this method has the additional benefit of plotting sequentially actor groups that are closer (in their preferences), hence aiding inter-group comparisons. The resulting iconographs display the limit cycles of the preferences to (substantive and institutional) components of SFM included in the survey. Interpretation of the results is based on the following levels of system behavior (as per Priesmeyer 1992; Musselwhite and Herath 2004, 2007): period 1, involving limit cycles in which dynamic movements oscillate in one basin of attraction (i.e. one quadrant) only; period 2, in which movements oscillate across two basins of attraction; period 4, in which all four basins/quadrants are visited and the pattern is repeated; and period 8, which plots three or more quadrants in chaotic non-deterministic patterns.

3.4 Results

Results of stakeholder groups' preferences of self-interest and economic versus altruistic and moral values are presented in Fig. 3.1. The stakeholder valuations follows a period 2 pattern, involving a limit cycles in which dynamic movements across stakeholder groups oscillate in two basins of attraction only. Notably, valuations of altruistic and moral values oscillate within only positive basin of attraction, indicating consensus in support of such values by stakeholders. In contrast, self-interest and economic values oscillate in both positive and negative basins of attraction, indicating some disagreements among stakeholders. Among altruistic and moral values, conservation of biodiversity and hydrological values, bequest values, and societal welfare values oscillate at high plane of the positive basin of attraction—indicating their perceived high significance among stakeholders. Existence values, on the other hand, oscillate in the lower plane of the positive basin of attraction. Among self-interest and economic values, sustaining cultural and heritage values, personal/household welfare, and future option values oscillate in higher plane of the positive basin of attraction. Current community extractive use values for subsistence needs oscillates in relatively lower plane,

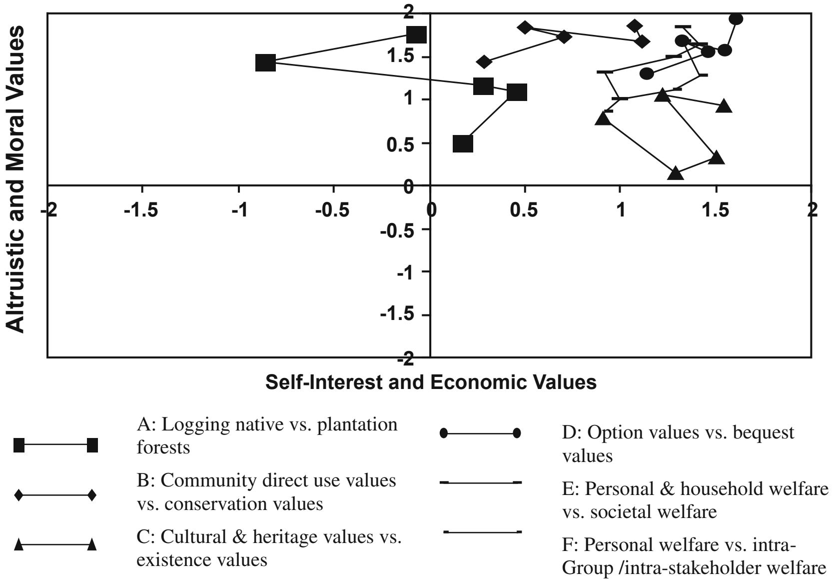

Fig. 3.1 Stakeholder groups' aspirational optimization of self-interest and economic versus altruistic and moral values. *Note* Point ordering of stakeholder values preferences: *A* estate, local community, ENGO, park authority, forestry authority; *B* park authority, local community, estate, ENGO, forestry authority; *C* local community, park authority, estate, ENGO, forestry authority; *D* park authority, local community, estate, ENGO, forestry authority; *E* park authority, forestry authority, ENGO, local community, estate; *F* forestry authority, park authority, ENGO, local community and estate

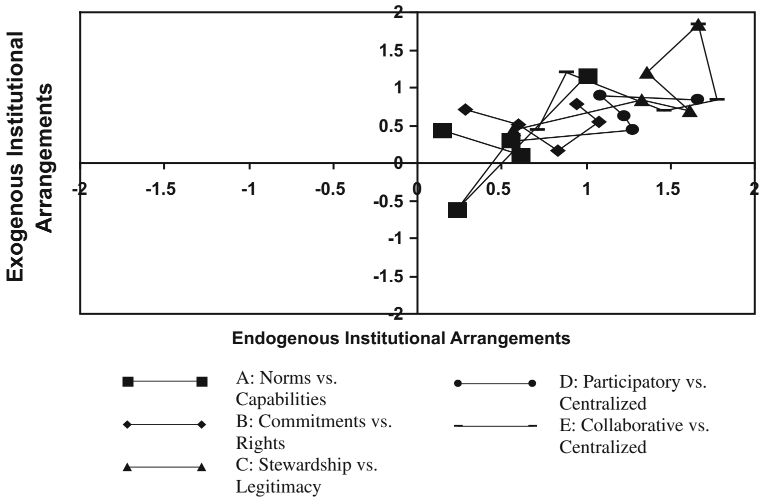

Fig. 3.2 Stakeholder groups' optimization of internal vs. external institutional arrangements. *Note* Point ordering of stakeholder values preferences: *A* park authority, ENGO, local community, forest authority, estate; *B* park authority, local community, estate, forest authority, ENGO; *C* park authority, ENGO, forest authority, local community, estate; *D* park authority, ENGO, forest authority, local community, estate; *E* park authority, local community, forest authority, ENGO, estate

albeit in a positive basin of attraction. Logging of high quality native timber species in natural forests oscillates between the lowest planes of positive basin of attraction and the negative basin of attraction—being a socially least desirable, and undesirable among some stakeholder groups—hence a socially divisive issue.

The results of stakeholder groups' preferences of formal and informal (as well as endogenous and exogenous) institutional arrangements are presented in Fig. 3.2. Generally, endogenous stakeholder institutional arrangement—involving self-endowments and capabilities of the stakeholder group or synergy with other stakeholder groups—oscillates in broader (low to high) planes of the positive basin of attraction. These are such aspects as social norms and networks of communication, SFM stewardship and commitments, as well as participatory and collaborative governance of forests.

Notably, among these, social norms, trust, and communication networks oscillate in the lowest plane of the positive basin of attraction, indicating stakeholder's low endowment of these attributes. On the other hand, the exogenous institutional arrangements—those involving endowments and capabilities that have to be guaranteed or enforced by an external agent/the state agency—oscillate mostly in lower planes of the positive basin of attraction, including a negative basin of attraction. These include stakeholder rights and legitimacy of claims and bureaucratic governance, plus financial and physical infrastructural capacity, which have to be guaranteed by a state-authority. Using a formal-informal dichotomy, it is also evident that formal institutions, such as state bureaucracy,

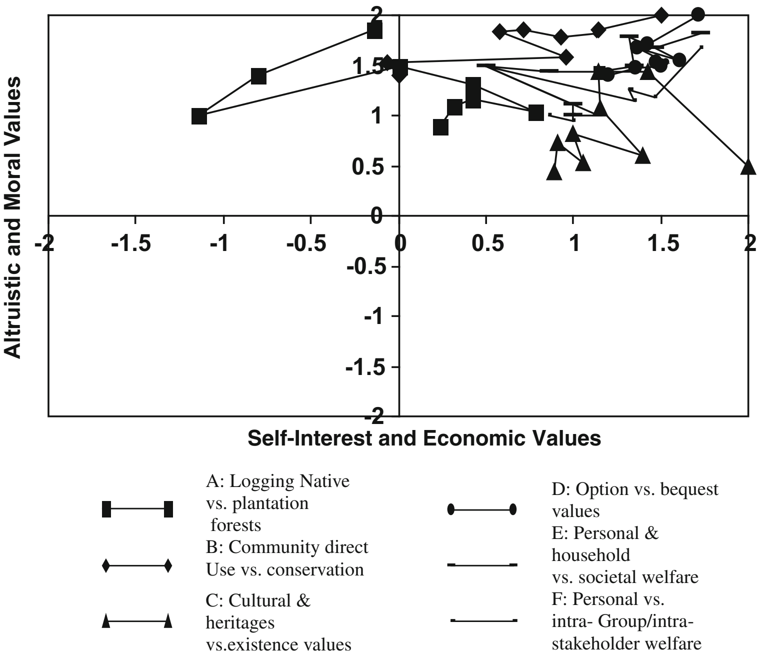

Fig. 3.3 Advocacy coalition groups' aspirational optimization of self-interest and economic versus altruistic and moral values. *Note* Point ordering of stakeholder values preferences: *A* social justice activist, local community, environmental committee, development activist, environmental-oriented, estate, environmental activist, park authority, forest authority; *B* environmental-oriented, forest authority, environmental committee, local community, development activist, park authority, estate, social justice activist, environmental activist; *C* park authority, estate, local community, forest authority, environmental-oriented, environmental committee, social justice activist, development activist, environmental activist; *D* environmental-oriented, park authority, environmental activist, local community, forest authority, estate, environmental committee, social justice activist, development activist; *E* environment-oriented, forest authority, environmental activist, development activist, social justice activist, environmental committee, local community, park authority, estate; *F* forest authority, social justice activist, park authority, environmental activist, environmental committee, development activist, local community

infrastructural and rights guarantees, oscillate in lower planes relative to informal institutions such as stakeholder commitments and stewardship. But as already observed, the latter are concurrently associated with low levels of trust, social norms, and communication network. Overall, the results show that preferences for institutional sustainability oscillate in lower planes.

Results of advocacy coalitions' preferences of self-interest and economic versus altruistic and moral values are presented in Fig. 3.3. The advocacy coalitions' preferences follows a period 2 pattern, involving a limit cycle in which movements oscillate in two basins of attraction/quadrants only. Like in the case of stakeholder-based preferences, preferences for altruistic and moral values oscillate within only positive basin of attraction. In contrast, self-interest and economic values oscillate in both positive and negative basins of attraction. Similarly, the oscillations of specific values in the planes of basins of attraction are similar to those recorded in Fig. 3.1. However, analysis based on advocacy coalitions increases the planes of oscillation/optimization in the basins of attraction, particularly with respect to self-interest and economic values. One particular pattern that stands out is that the polarity engendered by logging of native forests vis-à-vis their conservation (and logging plantations instead) is intensified. Compared to stakeholder based preferences, advocacy coalitions' preferences have more extreme views held by the community-development-advocacy-coalition (in favor of logging native forests) versus those of environmental-activist-advocacy-coalition (disapproves logging of native forests). These extreme points oscillate in, respectively, positive and negative planes higher than those occupied by similar extreme points in stakeholder based analysis held by local agrarian community and park authority, respectively.

The results of advocacy coalitions' preferences of endogenous versus exogenous (and formal versus informal) institutional arrangements are presented in Fig. 3.4. Like in the case of stakeholder-based analysis, generally, endogenous stakeholder institutional arrangements oscillate in broader (low to high) planes of the positive basin of attraction. In contrast, the exogenous oscillate mostly in lower planes of the positive basin of attraction, including a negative basin of attraction. But there are remarkably different results. First, the preferences are of a relatively chaotic, period 8, involving a limit cycle in which dynamic movements oscillate in three basins of attraction/quadrants, including two negative basins. Of particular interest is the financial and physical infrastructural guarantees, of which six (out of nine) advocacy coalitions feel particularly deprived, four of whose preferences oscillate in the negative basins. One coalition occupies a negative basin both in-terms of infrastructure and social norms and networks.

3.5 Discussion of the Results

The oscillation of economic and moral values in the same positive basin of attractions (Figs. 3.1 and 3.3), is consistent with the "both-and" principle of SFM. The outcome represents the dualistic behavior of agents which include both individualistic as well as altruistic and/or commitment, as expounded by Kant (2003a). This dualistic behavior is exemplified in pair-wise comparison of such binaries as community use values/and conservation of biodiversity and hydrological values; cultural and heritage values and/existence values; option values and/bequest values; plus, personal and household welfare and/societal welfare. The results are, thus, consistent with the SFM sub-principle of complementarity, which suggests that human behavior may be selfish as well as altruistic, people can have economic values as well as moral values, and people need forests to satisfy their lower level needs as well as higher level needs (Kant 2003a, 2005; Khan 2005). Interestingly, altruistic, moral, and higher level values—particularly conservation of biodiversity and hydrological values, bequest values, and societal

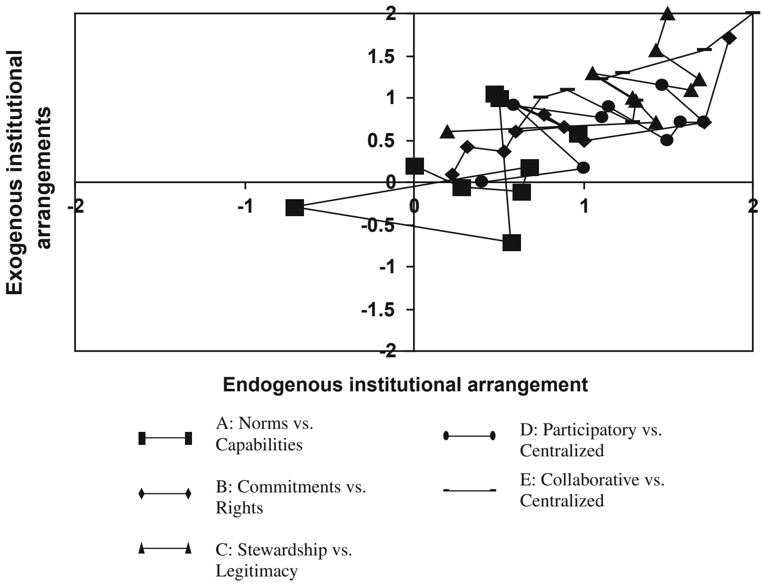

Fig. 3.4 Advocacy coalitions' institutional optimization of internal versus external institutional arrangements. *Note* Point ordering of stakeholder institutional preferences: *A* park authority, local community, environmental committee, development activist, environmental activist, forestry authority, estate, environmental-oriented, social justice activist; *B* local community, environmental committee, development activist, park authority, social justice activist, environmental-oriented, estate, forest authority, environmental activist; *C* park authority, environmental committee, local community, social justice activist, environmental-oriented, estate, forest authority, environmental activist, development activist; *D* park authority, forest authority, environmental-oriented, development activist, social justice activist, local community, environmental committee, environmental activist, estate; *E* park authority, development activist, local community, forest authority, environmental-oriented, environmental committee, social justice activist, environmental activist, estate

welfare—are of high relative significance (oscillate on higher planes of the positive basin of attraction) and least contentious. This complementarity is also applicable to endogenous and exogenous, as well as formal and informal institutions (Figs. 3.2 and 3.4). Interestingly, the states' bureaucratic (policing) approach, the dominant institutional paradigm preceding the SFM policy changes oscillates in lower planes of the positive basin of attraction relative to collaborative (joint forest management) and participatory (community-based) approaches introduced by the policy changes (i.e. GOT 1998, 2001). Evidently, the traditional approach is falling out of favor in the interest on multi-stakeholder engagement in SFM decisions and activities.

Study's results also correspond with other sub-principles of economics of SFM (Kant 2003a, b): namely existence, uncertainty, and relativity. The 'principle of existence' suggests that we cannot ignore the relevance of long surviving situations. Hence, we should focus first on achieving an economic understanding of the existing human-forest interactive systems, in order to be able to predict whether the effects of proposed changes would be, on balance, positive or negative. Based on Kant (2003a) premise, and Khan (2005) re-interpretation, the principle can lead to at least two inferences from our results. First, we consider the existing basins of attraction ('existing conditions') so as to change them if so desired. E.g. the case of low levels of trust, social norms, and networks of communications among some stakeholders, and particularly deprivations of financial and other infrastructural capacity necessary to attain SFM as observed in Figs. 3.2 and 3.4. While the latter finding calls for state's guarantees of financial (and other) SFM infrastructure, we contend that such cost burden can also be reduced if trust, communication networks and social norms are improved. In dealing with dilemmas of collective action, social networks of communication are relatively more effective than centralized bureaucracies, which emphasize vertical authoritarian networks, in which the local agent is a subordinate to the superior government agent. For example, bureaucratic centralization of forest resources in Tanzania has encouraged considerable inefficiencies e.g. 'red tape' and 'rent seeking' behaviors, plus local defiance to conservation (MNRTE 1995; Kajembe and Ramadhani 1998; MNRT 2003). It has been argued that in solving dilemmas of collective action, vertical networks—those linking unequal agents of dissimilar status and power—are less helpful than horizontal networks, bridging together agents of equivalent status and power (Putman 1993). Horizontal networks build social capital, such as social trust and norms or reciprocity, which can be used to aid multi-stakeholder negotiation in SFM. Social capital is needed to: effect and sustain the change towards collective action; and lower the costs of devising and enforcing rules governing the use of the common pool resource (Ostrom 1998). In our results, the growing interest in decentralized governance (participatory and collaborative approaches) is a desirable early switch point towards SFM. Another desirable switch point is the presence of advocacy coalitions, which seems to operate alongside formal organizations, informally linking agents from different formal organizations, to optimize in more planes of the basins of attraction than formal organizations. Very likely, these net-works of decentralized and informal organizations may increasingly foster trust, networks of communication and social norms eroded by many years of top-down bureaucratic management of forests in Tanzania.

The second inference is that we examine the existing basins of attraction that are resistant to change, and their survival is rendered as an equilibrium that is not stable but desirable. E.g. the social polarization related to logging of high quality native species. Evidently, regarding this value, actors are 'optimizing' in low planes of the positive basin of attraction, or in a negative basin of attraction. This is completely counter to the logic of land rent theory (Faustmann 1849) or efficiency based models of neo-classical economics. Notably, the preferences in this study are consistent with current policy debates and public choices in Kilimanjaro, which are centered on curbing the problem of unsustainable logging of high value native timber species, and increased attention to interventions related to protection of biodiversity, hydrological and aesthetic values—and shifting timber production to industrial plantations (MNRT 2003). The later are typically managed on the principle of maximum sustained yield (i.e. biological rotation). In native forests, timber is produced on neither economic rotation nor biological rotation, but sustenance of multiple values (timber, water, biodiversity, protection against erosion and landslides, tourism, etc.). Thus, even the observed negative optimization can be understood as a positive optimization of other desirable values, which are threatened by (i.e. compete with) timber extraction. Perhaps, the existence of this social polarization is helping against the extremes: i.e. liquidating forests through liberal markets, on the one hand, and strict preservation, on the other. The finding may fittingly correspond to Colander's (2005) remark: "in complexity story of sustainability, the resulting system is admired not for its efficiency, nor for any of its static properties; but for its very existence. Somehow the process of competition gets the piece of the economy together and prevents the economy from disintegrating. Observed existence, not deduced efficiency is the key to the complexity story line".

Interpreting the results in-terms of the existence principle also provide important insights regarding SFM by conservation vis-à-vis SFM by commercialization debate. Tanzanian forest and wildlife reserves are justified on registering tremendous economic and ecological benefits in aggregate values (CEDR 2001; MNRT 2003; UNEP 2001). Yet, regarding inter-stakeholder justice, many scholars suggest that such reserves often marginalize local communities, by curtailing their forest-dependent sources of livelihoods (Newmark 1993; Haule et. al. 2002; Goldman 2003; Kaltenborn et. al. 2005). This study's findings provide evidence that local resistance to conservation may not always be a result of the lack of conservation aptitude, but it may be due to contestation of existing conservation approaches or their distributional effects. This is further evidenced by the finding that current SFM commitments and stewardship (which oscillate in reasonably high planes of positive basins of attractions) (Figs. 3.2 and 3.4) are not supported with corresponding governmental guarantees in necessary finances and physical capacities, which oscillate in very low planes of positive basin of attraction for some actors and in negative basins of attraction for others.

The observed social polarization regarding logging native forests, can also find useful interpretation in the principal of uncertainty (Kant 2005). This principle suggests that due to uncertainties in natural and social systems, a social agent may typically not be in a position to maximize his outcomes, but will rather search for positive outcomes and learn by experience, such that resource allocation will be improved by adaptive efficiency, whose cumulated effects over time are likely to be more important than the achievement of efficiency at each point of time. This is akin to what Colander (2005) describes as complexity story of sustainability characterized by "reasonably bright individuals in an information poor environmental". Our analytical framework provides a scale of preferences with positive and negative scores with an uncertain (hesitation zone) in the middle. Presumably, this allowed individuals to factor-in uncertainty in their valuations. Where such uncertainty is perceived to be very high, reasonably, the stakeholder's optimize in the lower planes of the positive basin of attraction and in a negative basin of attraction close to zero (hesitation/uncertain zone)—e.g. regarding logging native forests. That is, given widely perceived uncertainty regarding the impact of logging tropical-rain forests on other ecosystem values such as biodiversity and hydrological values—and perceived high importance of the latter—agents' preferences are ridden with caution. Such caution may also be a result of feedback from prior observed impacts of logging on other ecosystem values (problems of illegal logging of high quality native timber species in Kilimanjaro are well documented—e.g. Lambrechts et al. 2002). Analytically, the outcome is consistent with addressing the possibility (non-stochastic) uncertainty—i.e. uncertainty inherent in available information examined by Kijazi and Kant (2011). Operationally, this is consistent with the application of the precautionary principle; which is also consistent with fundamental uncertainty (Lavoie 2005). It means that the future is uncertain, not only because we lack the ability to predict it, which is tied to epistemological uncertainty and procedural rationality, but also because of the ontological uncertainty—the future itself is in the making and the decisions that we are able to take will modify its course (Rosser 2001; Lavoie 2005). Thus, Lavoie, argue that when agents take decisions that affect them directly, fundamental uncertainty leads them to adopt a course of action that will generate safety. In Kilimanjaro, presumably stakeholder want to generate safety with regard to ecological goods and services of forests such as water (for drinking, irrigation and hydro-power), subsistence needs, aesthetics, recreation and tourism, medicinal uses, etc., that are known to contribute greatly to the local, regional and national welfare. The same reasoning is applicable to the preferences for increased community access for current direct-use (extractive uses) of non-timber values, which though oscillates in a positive basin of attraction, in pair-wise comparison, it oscillates in a lower plane relative to its counter-part choice i.e. conservation of biodiversity and hydrological services.

All results considered together, adhere to Kant's (2003a, b) principle of relativity, which suggest that optimal solutions are not universal but rather situation specific; in many cases they will involve important non-market forces. The analysis is suitably encompassing in that it is contextual—the values and interests can be interpreted within a much broader framework of related to institutions, social well-being and social welfare, rather than the non-contextual Faustmann's land rent economics. Contextually, the results need to be interpreted in at least three frames of reference. First, Kilimanjaro forests are not private forests, but 'golden woods' of the nation by law, and different stakeholders entrusted with its management are obligated to manage its forests to maintain sustainable flow of multiple products for general welfare and future generations (MNRT 2003). Such obligations assume even high historical and contemporary significance given that Mount Kilimanjaro is the oldest protected area by contemporary state law in Africa, and is presently a world heritage site (Lambrecht et al. 2002). Second, the survey is based on the existing SFM policy (GOT 1998, 2001), and the results such as increased interest towards participatory and collaborative approaches to forest management are to be understood in the context of that policy. Third, the economy of communities on the slopes of Kilimanjaro is strongly inter-woven with the ecological goods and services from Mount Kilimanjaro forests (wood, water, tourism, non-timber products, etc.). Also, the communities have centuries old history of managing and bequeathing natural resources: e.g. the traditional "Chagga-home-garden" agro-forestry systems (O'kting'ati 1984), government allocated half-mile strips of buffer zones of the natural forests (MNRT 2003), and traditional irrigation channels from Kilimanjaro forest water catchment (Gillingham 1999). We presume such experiences have also played a role in informing actors' forestry value and institutional understandings and valuations. Thus, SFM interventions, henceforth, can derive tremendous inputs from such experiences.

We think our results can be read better if the sub-principle of complementarity is also interpreted in relativistic sense. While our analysis and findings agree with Kant's (2003a, 2005) and Khan's (2005) "both-and" characterization of forest actors behavior, we think this characterization is complete only if viewed in a relativist sense in that an altruistic value at one level of optimization can become self-interest value at a higher level of optimization: e.g. at household level, optimizing with household rather than mere personal goals is altruistic; but this can conceivably become selfish, at community level, if it ignores broader community needs. Similarly, current non-use values such as option, bequest and existence values are all altruistic in essence. However, in relativistic sense, bequeathing is more altruistic in its equal consideration of future generations; while existence values are more so in their equal consideration of non-human species. E.g. our findings (Figs. 3.1 and 3.3) point out that inter-generational altruism (bequest) is more embedded in the culture than altruism to non-human species (existence). This outcome implies that SFM policies geared towards bequeathing forest to future human generation may receive little social resistance. But those geared only toward preserving other species for their own sake may require educational and/or public discussion programs to engender increased social sensitivities to such species.

Finally, while the result fit with sub-principles of SFM economics (complimentarity, existence, uncertainty, and relativity), we believe that in the context of complexity theory, they can be read better through a higher, unifying principle—The principle of interdependence; whereby all human and non-human components of eco-systems, including human economy, are recognized as inter-dependent actors and processes. Literature has indicated that most forest goods and services tend to have an inter-dependent (vis-à-vis perfect substitution) relationship with each other and/or with man-made capital (Costanza et al. 1997). Given value interdependence and externalities, market prices are only one category of scarcity signals; there are many social, cultural, and environmental signals of resource scarcity (Kant and Lee 2004, Kijazi and Kant 2010). The study's findings highlight the significance of these interdependences and presence of externalities and non-market scarcity signals in forest ecosystems. For example, in Kilimanjaro, currently high value native species—e.g. Camphor wood (*Ocotea usambarensis*), African Pencil Cedar (*Juniperus procera*) and Podo (*Podocarpus mylanjianus*)—are being illegally harvested due to high market demand (Lambrechts et al. 2002). Thus, the negative oscillation of some stakeholder's scores of logging native timber species is a non-market 'social' signal of scarcity indicating perceived negative effect (externalities) of timber extraction on other values. Presence of several values in higher planes of the positive basin of attraction implies that such values are considered inter-dependent and complimentary in stakeholders' welfare space. In contrast to this interdependence/complementarity, the neo-classical economics notion of gross substitutability in allocation of natural capital assumes full commoditization of ecosystems by markets. But according to Kant (2003b), ecosystems cannot be sub-divided and commoditized and ecosystem capital satisfies differentiated needs, and, hence, gross substitution between different components of ecosystem capital or between ecosystem capital and man-made capital is not possible. Polanyi (1944, 2001) asserts that 'what we call land is an element of nature inextricably interwoven with man's institutions. To isolate it and form a market for it was perhaps the weirdest of all the undertakings of our ancestors.' Yet, the Faustmann forest land rent theory (op cit.) and its neo-classical economic derivatives are founded on isolating the forest land from human institutions and situating it in a liberal market economy under the neo-classical investment theory (Möhring 2001). Hence, complexity theory including market and non-market values plus market and non-market social institutions is more realistic in delivering SFM solutions than the land rent theory and neo-classical economics.

The complexity framework, based on our understanding of inter-dependence, is more likely to direct our attention from exclusive concern with economic efficiency, to address distributive, procedural, and ecosystem justice matters which may include the rights and interests of both human and non-human species. Consequently, the "both-and" and inter-dependence principles becomes the organizing principles of SFM through ecosystem sustainability, given that an ecosystem signifies a community of interdependent members. The members of an ecosystem include all those with dependency or legitimate interest in the functioning of the ecosystem. Viewing SFM through the lens of interdependent actors and processes working towards ecosystem sustainability—including complex interaction of nature, culture and ethics—draws attention to the question of legitimacy of claims that can be made on behalf of all the components of the ecosystem. This allows the appropriate accommodation or balancing of these claims. In essence, Figs. 3.1 and 3.3 depict a dynamic oscillation of such claims with respect to human values and ethics. Figures 3.2 and 3.4 depict claims related to institutions. Then, stability and/or desirability of basins of attraction of such claim, or otherwise, can guide sustainability interventions. In other words, to satisfy this more fundamental conception of SFM via ecosystem sustainability is to find an ethically acceptable relationship among all the competing and complementary interests of the members of the community. Normatively, the goal is to obtain a sustainable community in which the various interdependent components of the ecosystem (e.g. the natural ecosystem elements, social structures, and institutional structures) interact with each other in a way that contributes to the good of the others and to the good of the whole system.

3.6 Conclusions

The study has revealed early indicators of switch points both towards and away from sustainability. For example, the study reveals more stable limit cycles for values and less stable limit cycles for institutions. Hence, institutional interventions, rather than value sensitizations, may be more critical interventions for SFM in Kilimanjaro. The results also indicate desirability of increased forest actors' engagement through participatory and collaborative approaches—vis-à-vis the conventional top-down government bureaucratic interventions—as desirable switch points towards SFM. Additionally, the weights accorded to different values or institutional attributes by stakeholders can serve as early signals of the (positive and negative) distributional changes resulting from forest policies and management interventions currently in place related to these values and institutions. The observed complex interactions of forest actors (stakeholders and advocacy coalitions) and their heterogeneous and dynamic values and interests signify the need for reasoned and weighted evaluation of multiple values and interests in choosing our criterion and goals of sustainability. The results also imply that this can hardly be done through the representative behavior of the Homo economicus, and as a matter of intra and inter-generational justice and analytical realism, the evaluation should involve heterogeneous forest actors with stake in SFM system in question.

Our analysis has also demonstrated that complexity theory can deal with foundational limitations of neo-classical economics including Faustmann economics of land rent theory. Hence, in contrast to the more restrictive neo-classical economics, forest economists may find complexity theory to be a useful tool in the analysis of SFM alongside the so called 'heterodox economics' which have recognized complexity, multiplicity, dynamism and inter-relatedness of the real world. Forest economists have a challenge to continue to develop tools more suited for dealing with this complexity. Given advances in natural sciences such as physics and meteorology, and recent adoption of complexity models in management sciences, forest economists can learn and adapt conceptual models and analytical tools from these fields.

We believe our contribution in this regard is, but, a little step in the right direction towards a development of a more comprehensive complexity theory in SFM. We, nonetheless, acknowledge limitations endangered by the lack of time series data in this study. This has limited us to spatial limit cycles, and constrained us from analyzing temporal limit cycles of stakeholder behavior. Also for the same reason our analysis has been limited to geometric (iconographic) depiction of actor-system dynamics.

Finally, complexity based analysis can provide information more suited to economic and policy interventions in SFM because of the following reasons. First, in addition to quantitative results, it is capable of linking them with a descriptive profile of human systems and ecological systems including their parts and interactions. Second, it is holistic, comprehensive and trans-disciplinary. Third, it is based on actual preferences of real human beings rather than on the assumed preferences of an imaginary super-rational representative agent. Fourth, it describes system dynamics and associated stability and feedback. Fifth, it describes social significance of diverse ecosystem and social values and their interrelations instead of using an arbitrarily single dimension market value. Sixth, it can look at different levels/scales of system structure and processes, and facilitates a flexible analytical and planning process. Seventh, it can implicitly incorporate ethics of quality of life, well-being, and ecosystem integrity. Eighth, it can specify required systemic limits to behaviors.

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Chapter 4
Modeling Forest Sector Structural Evolution with the Experience-Weighted-Attraction-Learning (EWA-Lite) Algorithm

Olaf Schwab and Thomas Maness

Abstract The conventional economic forest sector models have limited spatial applications. In this chapter, we present an agent-based forest sector modeling framework (CAMBIUM) that enhances spatial relevance. The model enables the study of industry interactions and strategic decision making in an environment that is characterized by continuously changing conditions in both the underlying resource inventory and finished product markets. In this model, decision processes are modeled using an implementation of the self-tuning experience weighted attraction learning algorithm (EWA-Lite). This algorithm allows agents to adjust their learning behavior along a continuum between reinforcement learning and belief learning depending on the perceived stability of their environment. The use of three distinct investment strategies (capacity expansion, process innovation, and sustainment) was found to be sufficient for achieving agent differentiation and dynamic industry structure equilibrium. The number and relative size of competitors is determined by repeated agent interactions, and can be interpreted as an emergent property of the inventory, industry, and market system.

Keywords Adaptive system · Agent based models · Agent interactions · Canada · Computational economics · Forest industry · Learning behavior · Multiple agent systems · Self regulating systems · Strategy

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O. Schwab (✉)
Science and Policy Integration, Natural Resources Canada,
580 Booth Street, Ottawa, ON K1A 0E4, Canada
e-mail: olaf.schwab@nrcan.gc.ca

T. Maness
Forest Engineering, Resources and Management Department, Oregon State University,
Peavy Hall 204, Corvallis, OR 97331-5706, USA
e-mail: thomas.maness@oregonstate.edu

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4.1 Introduction

Conventional forest economics has recognized the interdependence of resource inventory dynamics, timber supply and forest products markets (Andersson et al. 1986; Buongiorno 1996). The first model incorporating both roundwood supply and finished product demand was published by McKillop (1967). This model derived equilibrium price levels from econometrically estimated supply and demand equations for solid wood and paper products. Subsequent studies have predominantly focused on integrating the spatial aspects of roundwood and forest products markets. Lönnstedt (1986) developed a two sector model of domestic and international production and applied it to the Swedish forest products sector. In a later study, Lönnstedt and Peyron (1989) demonstrated how the same framework can be applied in analyzing regional markets. These small sector models require relatively few parameter inputs for estimation and can therefore be used as an initial approximation for directing the subsequent implementation of larger, more complex models (Wibe 2005).

The Timber Assessment Market Model (TAMM) is an example of a national level forest sector model (Adams and Haynes 1980, 1996). This model computes equilibrium trade flows and price levels for 12 supply and 6 demand regions in the United States and Canada. Regional forest products industries are modeled using aggregate capacity estimates and econometrically estimated supply functions (Adams and Haynes 1996). Other large-scale models include the global trade model (GTM) developed by Kallio et al. (1987). The EFI-GTM is a direct successor of the GTM, disaggregating data on supply regions and technologies (Kallio et al. 2004, 2006). Northway and Bull (2007) expand on this approach in the International Forest and Products Trade Model (IFFP) by modeling resource availability using embedded country-specific forest estate models.

A common characteristic of these classic economic forest sector models is their macroeconomic approach, using aggregated data and linear functions for describing resource inventory dynamics, manufacturing processes, and demand. While these models are spatial in nature, it is not possible to interpret modeling results at a scale that is finer than their constituent spatial and functional entities.

Economies can be described as largely self-regulating and self-determining systems (Vanderburg 1985). In the case of the forest sector, the boundaries of self-regulation and self-determination are defined by resource inventory growth rates and market demand for finished forest products. Multiple agent systems (MAS), and in particular agent-based computational economics have been introduced as tools to model interdependencies and feedback loops between microstructure and macrostructure quantitatively (Lempert 2002; Tesfatsion 2002). An early example of using MAS for wood products allocation problems is given by Säaksjärvi (1986), who recognized that unequal cost allocations may make individual companies unlikely to cooperate and support a globally optimum wood allocation solution. Cooperative games are shown to be effective in determining fair compensation for wood sharing agreements. Gebetsroither et al. (2006) presented a model of self-organization in socio-economic and ecological processes to reduce the amount of uncertainty that conflicting objectives and complex interdependencies introduce into forest management planning. Modeling these processes as self-organizing subsystems eliminated the need for direct hierarchical control and made it possible to implement an adaptive management system for achieving desired conditions with minimum interventions. Moyaux et al. (2004) analyzed the effects of collaboration on supply chain performance using the Quebec forest products industry as the primary case study. This study demonstrated that selfish agents have an incentive to at least partially collaborate, and that, from a game theoretic perspective, no equilibrium existed when at least one agent did not collaborate. Gerber and Klusch (2002) presented an information and trading network that coordinates plans between producers, buyers, retailers and logistics companies in the agriculture and forestry sectors. The network was designed as MAS due to its inherent robustness, flexibility, and ability to self-organize in the absence of direct human intervention. D'Amours et al. (2006) developed a MAS approach to lumber production planning that offers significant time savings relative to manual planning.

When economic agents are either incapable of or unwilling to optimize, it becomes impossible to deduce market outcomes (Axelrod 1997; Rammel et al. 2007). Reasons for this type of non-optimal behavior include irrational or bounded rational behavior, a dynamic and continuously changing environment, and competing objectives among different agents.

Agent-based computational economics (ACE) is a method for developing and exploring economic models as complex adaptive systems, and ACE therefore makes it possible to observe transition processes between equilibria. Using object-oriented programming techniques, it is possible to model economies as systems of autonomously interacting agents that do not necessarily act perfectly rational, or possess complete information about their environment.

ACE is part of a third developmental stage in socioeconomic modeling, where agent interactions are explicitly incorporated to improve the explanatory power of earlier macro-simulation and micro-simulation models (Macy and Willer 2002). Economies can be described as largely self-regulating and self-determining systems (Vanderburg 1985). While each individual process within such a model may be quite simple, their simultaneous and repeated implementation creates 'artificial histories' that make it possible to study processes of interest, such as patterns of resource utilization and industrial organization (Axelrod 1997; Bonabeau 2002; Cao et al. 2009).

The agent-based forest sector model presented in this chapter is similar to a model described by Gebetsroither et al. (2006), but expands on it by integrating mechanisms for learning and individual strategic choice. Bounded rationality has long been recognized as an important factor in decision making processes (see for example Lindblom 1959; March 1978). Dieckmann (1995) defines the main characteristics of bounded rational decision models as inertia, limited memory, and the potential for suboptimal choice.

Decision processes in agent-based systems can be simulated with the self-tuning experience weighted attraction learning algorithm EWA-Lite (Ho et al. 2001). This approach combines each agent's repeated assessment of expected strategy payoffs with information on how each strategy performed in the previous periods and how drastically the learning environment is changing. The EWA-Lite algorithm allows agents to adjust their learning behavior along a continuum between reinforcement learning (for stable environments) and belief learning (for instable environments). This algorithm has been found to correspond well to human behavior (Nawa 2006) and consistently performs equivalent or better than other learning algorithms (Camerer and Ho 1998; Ho et al. 2001). The unique feature of EWA-Lite is that it only requires a priori estimation of one parameter that describes the sensitivity of an agent's decisions to changes in its learning environment. All other parameters are being determined and adjusted endogenously, making this decision model uniquely suitable for the requirements of 'no modeler intervention' (Tesfatsion 2002) and the minimal set of necessary processes and parameters in agent-based modeling (Macy and Willer 2002). These requirements ensure that a model is fully specified and capable of generating the phenomena of interest endogenously, while still being sufficiently abstract to support the analysis of potential causal relationships.

In this chapter, we develop Cambium, an agent-based forest sector model that is capable of simulating how strategic decisions and inter-agent competition affect the emergence of industry structures, firm survival, and industry resilience. Following this introduction, the parameters and methods used in modeling forest inventory, product markets, industry agents, production strategies and strategic choices are described in detail. The third section presents sample outputs from a 200 year simulation of 15 sawmilling agents on a hypothetical 3.3 million hectare land base consisting of 13,000 tiles, followed by a sensitivity analysis of model outputs. Finally, the distinguishing features of the Cambium model relative to conventional forest economics models will be summarized.

4.2 Methodology

The agent-based forest sector model presented in this chapter is designed to model agent differentiation and industry structure development. Decisions in the Cambium model are based on agents' individual measures of innovativeness and risk aversion, expected payoffs and experiences with the different strategy options, and competition with other agents for raw material inputs and profits in a competitive lumber market. Agent interactions occur both directly and indirectly. Direct interactions play a major role in modeling the decision making process using the evolutionary learning algorithm EWA-Lite, where changes in other agents' behavior are observed to assess the stability of economic conditions. Indirect interactions occur in the allocation of roundwood, market trading of lumber, through market signals in forming price expectations for lumber products, as well

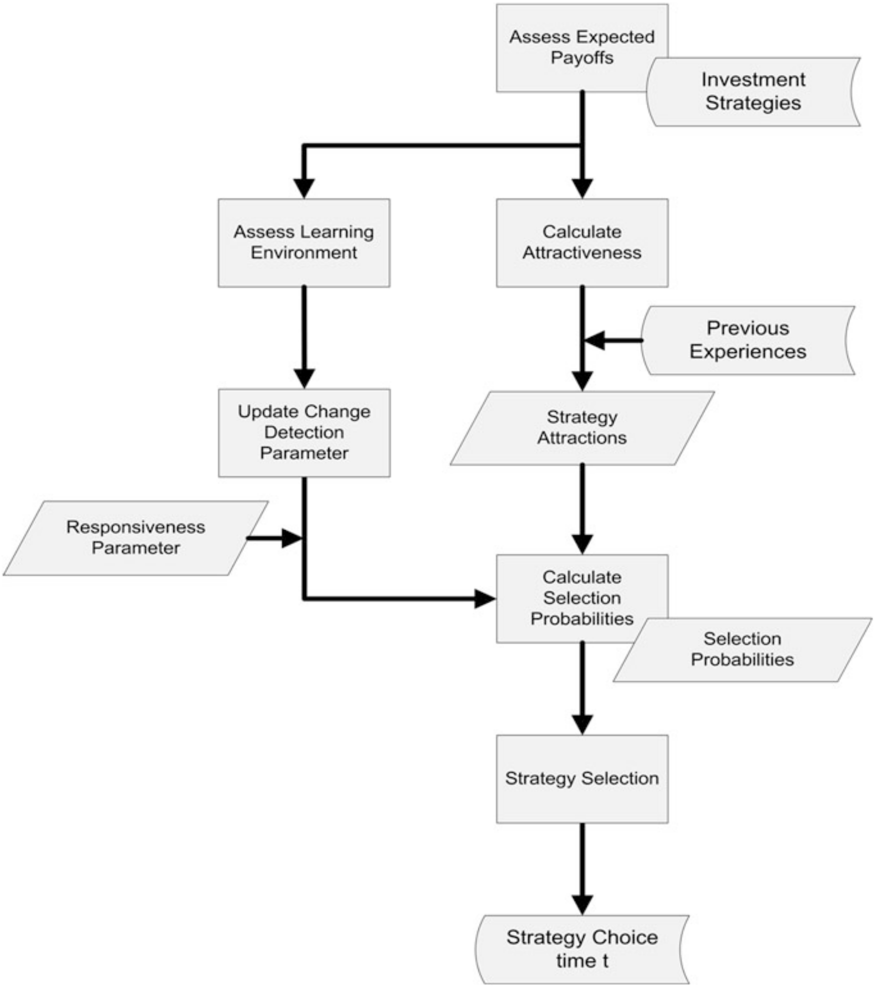

Fig. 4.1 Modeling decisions with experience weighted attraction learning

as during the stumpage bidding process with the highest bidder determining base rates for the current period.

Decision processes in the Cambium model were simulated based on the self-tuning experience weighted attraction learning algorithm (EWA-Lite) (Ho et al. 2001). The EWA-Lite algorithm was adapted to the particular structure of the decision problem facing each agent in the forest sector model. The components and structure of the decision process are summarized in Fig. 4.1 and described in detail below.

Based on their perception of the learning environment in any given period firms can choose from three district investment strategies. These are: (1) endogenous growth through capacity expansion; (2) improving product recovery through process innovation; and (3) sustaining current operations by periodically replacing outdated equipment.

An expected payoff is calculated for each available strategy using infinite horizon net present value calculations. The expected payoffs are translated into attractiveness values based on the agent's previous experience with implementing each strategy, placing the highest emphasis on recent experiences. Positive previous experiences increase the current attractiveness of a strategy, while negative experiences decrease attractiveness.

At this stage, the agent assesses the stability of its learning environment. The change-detection parameter plays a critical role in adjusting decision behavior. The learning environment is stable when the parameters of interest change relatively little. Depending on model settings, the change detection parameter reflects either the frequency with which competitors choose specific strategies, or the quantities and price range of products traded in the market. In stable environments past experiences are a good predictor for future conditions, allowing agents to exploit well performing strategies with little risk. In contrast, past experiences are a poor predictor of future conditions in rapidly changing environments, and should therefore be discounted more strongly. This allows agents to enter an exploration phase, where decisions are once again mainly based on the expected payoff for each strategy.

The probability that a firm selects a given investment strategy is determined using a logit response function that takes into consideration each agent's individual response sensitivity. The strategy choice for a specific period is then determined by random draw. Equations for calculating and updating the decision parameters are described by Ho et al. (2001). It is expected that over time economic agents will settle into a stage of dynamic equilibrium where occasionally firms revise their strategic choices and displace another firm, but where the overall industry structure remains relatively stable (Camerer and Ho 1998).

A review of the economic literature indicated that capacity expansion and process innovation are some of the primary means by which companies achieve specific competitive positions (Besanko and Doraszelski 2004; Hansen et al. 2007). A third strategy, sustainment, was added to accommodate conditions where neither continuing innovation nor capacity expansion are technologically and economically feasible. These three distinct investment strategies were found to be sufficient for achieving agent differentiation and an associated dynamic industry structure equilibrium.

Industry structure is tracked using two closely related measures: (1) a capacity-based industry concentration curve, and (2) the Herfindahl–Hirschman Index (HHI). When market share is measure in percentage points, the HHI can range from 1/n (with n being the number of companies in the market) to 10,000. A small HHI represents competitive markets without dominant players, while higher HHI values indicate increasing market concentration. Commonly used interpretation thresholds relate to no market concentration (HHI<=1,000), moderate concentration (1,000<HHI<=1,800), and high levels of market concentration (HHI>1,800) (Calkins 1983; U.S. Department of Justice Antitrust Division 2007).

The agent-based forest sector model was coded in Java using the Recursive Agent Simulation Toolkit [Repast J] program libraries (North et al. 2006; ROAD 2008). The modeling environment was chosen based on reviews and comparisons by Tobias and Hofmann (2004) and Railsback et al. (2006). Important factors in this decision were the ability to interface with geographical information systems, cross-platform transferability of the resulting model, and well-documented open access program libraries.

4.3 Model Structure

The geographical range of the forest sector model is defined by a rectangular grid, with forest stands being represented by individual lattice tiles. Both the size and the number of tiles can be defined by the model user. Default settings are 13,000 tiles of 256 ha each, but the model has been successfully tested with landscapes of up to 1.4 million tiles. The forest inventory on each tile is described by stand age and merchantable volume. Stand growth is modeled using a sigmoid growth curve (Pretzsch 2001). The default forest inventory is modeled as a randomly distributed normal forest, where each age class is represented with an equal area. The use of this normal forest model removes the effects that an unbalanced age class structure and resulting timber supply shortages may have on industry structure development. However, this hypothetical, randomly distributed normal forest can at a later stage be replaced with empirical forest inventory data to conduct analyses for specific geographic regions.

At this stage of model development, the market for lumber products is modeled using a linear demand function with a demand elasticity of -0.5 (Abt and Ahn 2003). Forest growth and lumber demand constrain the maximum size of the forest sector. The number and relative size of competitors in the forest sector is determined by repeated agent interactions, and can be interpreted as an emergent property of this inventory, industry and market system.

Economic agents are defined by their location on the landscape, production capacity, product recovery factor, innovation success rate, strategy response sensitivity and an initial capital endowment. A user-defined number of agents is placed on the landscape randomly, establishing a starting industry configuration with uniform production capacities and capital endowments. The starting values for each individual agent's product recovery factor, innovation success rate, and strategy response sensitivity are determined by random draw from a uniform distribution with user-defined minimum and maximum values.

The agents act and interact with each other, as well as with the forest inventory and the lumber products market as diagrammed in Fig. 4.2.

At each time interval, the sawmill agent proceeds through the sequence of planning and implementation steps shown in bold. Agents become insolvent as soon as their working capital falls to zero. These agents become inactive and are removed from the simulation environment upon completion of the current time

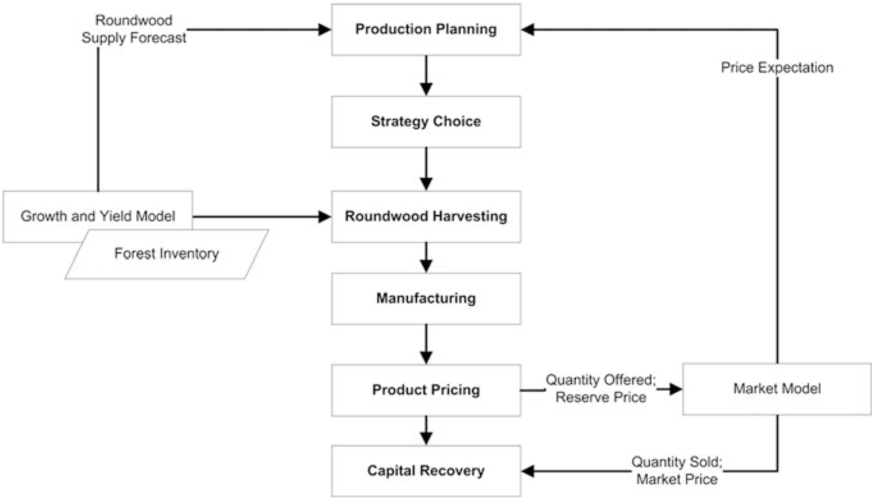

Fig. 4.2 Information flow between agents, markets, and resource inventory

step. During production planning, agents form price expectations for their finished products based on predicted product demand and the observed production capacity of competing sawmills. This forecast is not necessarily equivalent to the period's realized market price, since competitor's choices regarding capacity expansion and capacity utilization cannot be observed until the following period.

Tentative production targets are developed for all three investment strategy options as a function of predicted market demand and price levels, as well as each agent's production costs and capacities. Production targets are set in an iterative procedure by adjusting targets downwards until a solution is found that is expected to be financially feasible over an infinite horizon given current expected market conditions.

Financial feasibility is defined as the ability to meet projected cash flow requirements for equipment amortization, as well as stumpage and other production costs. Agents are removed from the simulation if no financially feasible strategy can be found.

4.3.1 Strategy Definitions

Capacity expansion is one of the means by which companies achieve their relative competitive position in developing markets (Reynolds 1987). In this model, the endogenous growth strategy is designed to achieve maximum production capacity subject to constraints posed by the availability of capital and roundwood. Capital availability is dependent on the agent's profitability and cumulative net earnings. Capacity expansion occurs in multiples of a user-defined increment and is restricted to cases where previous manufacturing equipment investments have been fully amortized.

Companies also have the ability to remain competitive through innovation, by introducing new or improving existing products, processes, and business systems (Hovgaard and Hansen 2004). The commodity orientation of the Canadian forest products industry has resulted in a very strong focus on achieving high levels of production efficiency (Crespell et al. 2006). Therefore, successful innovation is modeled as improving product recovery while lowering variable manufacturing costs. Innovation can occur within an industry specific user defined range of product recovery factors. Default values for the sawmilling sector are a lower bound of 5.32 m^3 per thousand board feed (mbf) and an upper bound of 3.32 m^3/mbf (Haynes 2003). The expected payoff from implementing an innovation strategy was calculated based on the user-defined costs per innovation initiative and the agent-specific innovation success rate. Multiple innovation initiatives can be undertaken in a single period. This expected payoff can differ from the realized payoff at implementation since the success of each innovation initiative was modeled using a random draw from a uniform distribution.

A sustainment strategy was included to account for situations where neither innovation nor endogenous growth would generate a positive payoff. For the sustainment strategy, agents replace equipment only at the end of its user defined lifespan. Production targets are determined within the bounds set by the current production capacity. Lumber recovery rates remain unchanged since improvements in product recovery can already be obtained by implementing a process innovation strategy.

4.3.2 Stumpage Rates, Roundwood Harvesting, and Lumber Production

Stumpage charges are modeled based on a competitive bidding process. To establish a global stumpage base rate, each agent submits a maximum bid ($/$m^3$) net of road access costs. Access costs are user-defined as a fixed rate per kilometer and cubic meter. The maximum stumpage bid is based on each agent's individual cost structure and profit targets, as well as expected and historical market prices for finished products. The global base stumpage rate for the current period is then set to the value of the highest received bid. For each harvested tile, agents incur stumpage costs (the stumpage base rate) as well as mill-specific harvesting and transportation costs to the mill gate.

Tiles are queued for harvest using an oldest-first harvesting rule, and allocated to mills based on minimum transportation distance. Since stumpage rates are adjusted to account for harvesting and transportation costs to the mill gate, this allocation procedure guarantees the highest revenue to the owner of the forest resource. At a later stage of model development, it may be possible to implement a stumpage bidding process that dynamically adjusts the bidding behavior for each individual tile based on current market expectations and the winning bids for previously allocated tiles.

Agents continue harvesting until the roundwood demand for the current period is met or no additional roundwood is available without exceeding sustainable harvest levels. Agents incur costs for harvesting and transporting roundwood, as well as stumpage costs. During the manufacturing process harvested roundwood is converted into dimensional lumber and chips based on each agent's lumber recovery factor. Variable operating costs are then deducted from the agent's working capital.

4.3.3 Product Pricing and Market Trading

At the end of the manufacturing step, agents set a minimum sales price for their current lumber production. The reserve price is based on average production costs for the period, as well as expected and observed market prices. The lowest price they will accept for lumber produced during the current period is one that just covers their cost and an agent-specific minimum profit expectation. Unsold inventory from previous production periods may be sold at a loss once reserve prices have been adjusted accordingly. During this pricing process, unsold inventory from previous periods is discounted by a user-defined percentage and offered on the market. Trading units are defined by an owner (the producing agent), a product category, a reserve price, and a quantity offered.

Market trading occurs once all agents have submitted their trading units. These trading units are sorted with ascending reserve price, and matched to the market demand. The trading result for a non-saturated market is shown in Fig. 4.3, while a trading in a saturated market is shown in Fig. 4.4. Trading units are shown as grey rectangles, with the width indicating the volume offered, and the height indicating the reserve price.

As shown in Fig. 4.3, all trading units offered in the market are traded, with the last trading units' reserve price determining the current market price p_1*.

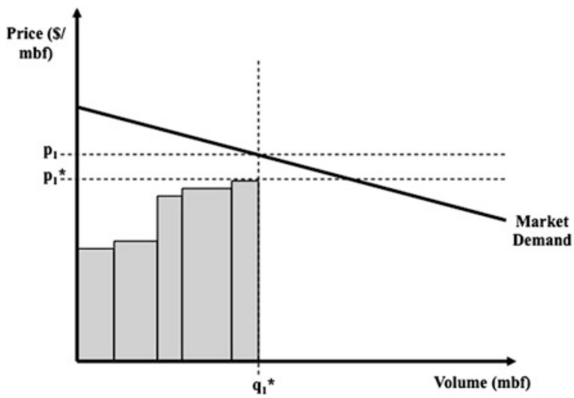

Fig. 4.3 Trading in a non-saturated market

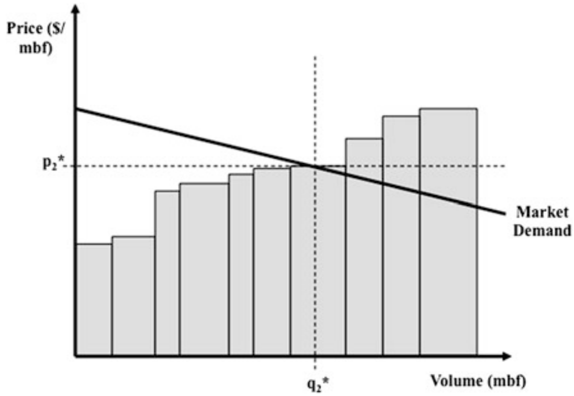

Fig. 4.4 Trading in a saturated market

Companies observe the difference between the realized market price p_1* and the predicted market price p_1, and adjust profit targets and production plans accordingly. In contrast, in Fig. 4.4 market supply exceeds demand. Only the first six trading units and a portion of the seventh are traded at price p_2*, for a total volume of q_2*. For each traded unit, the owning agent realizes a gross revenue defined by the market price p* and the volume sold. The remaining trading units are returned to the producing agents as unsold inventory.

The elements outlined in Fig. 4.2 are implemented for each modeling time step. Simulation speed is mainly affected by the number of tiles in the landscape and the number of companies that are being modeled.

4.3.4 Model Output

Figure 4.5 shows a screenshot of the model with 15 companies on a hypothetical uniform land base consisting of 13,000 tiles. These values were selected to create sufficient competitive pressure between the companies while avoiding a split into smaller spatial sub-markets. An average simulation speed of 10 years per second was observed for this configuration, enabling model users to rapidly test the effects of different configurations on emerging industry structures.

The display window in the top left corner of Fig. 4.5 shows the model landscape as a network of tiles in a grid pattern. Light colored tiles indicate young stands and darker colors indicate mature stands. Active sawmilling agents are shown as red dots, while insolvent agents are shown as red crosses. The bar graph below the grid displays the frequency with which each investment strategy (endogenous growth, innovation, sustainment) was chosen in the current period. The graphs in the centre column track market prices ($/mbf), traded volumes (mbf/year), harvest levels (m^3/year), and stumpage rates ($/$m^3$) respectively. These graphs provide a high level summary of harvesting activities and market outcomes.

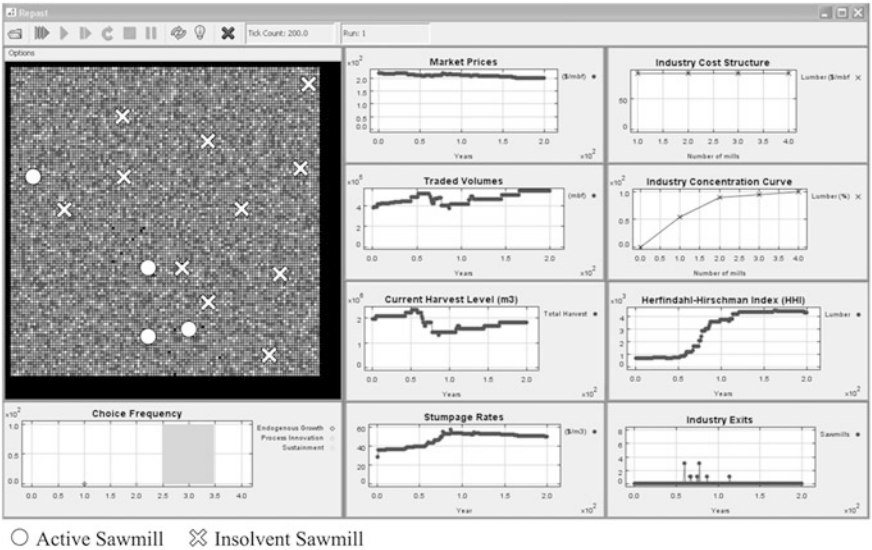

Fig. 4.5 Cambium model screenshot

The graphs in the right column address issues related to current industry structure. The topmost graph shows current production costs for individual agents (\$/mbf) from lowest to highest. It reflects the realized costs for production, harvesting, and transportation for the current time step. The industry concentration curve below shows each agent's market share (%), ordered from largest to smallest. This concentration curve provides a snapshot of the current industry structure. The graph below tracks the Herfindahl–Hirschman Index (HHI), providing a measure of how industry structure is changing over time. The final graph on the bottom of the right column indicates when agents became insolvent and exited the simulation.

Overall, the graphs in Fig. 4.5 belong to two distinct groups. The first group consists of the overview map, industry cost structure, choice frequency, and industry concentration curve. This group provides continuously updated snapshots of current conditions in the simulation model. The second group consists of market prices, traded volumes, harvest level, stumpage rate, HHI, and industry exits. This group of charts is cumulative over the entire simulation run in order to provide information on how a specific industry structure was attained. The use of simulation time as the common x-axis for the second group also facilitates cross-comparison for identifying effects that may have a causal relationship.

A Monte-Carlo analysis of 100 simulation runs was conducted to assess the sensitivity of model results to the stochastic components of the model. For this analysis, all random parameters were drawn from a uniform distribution. For each 200 year simulation run a population of 15 sawmilling agents was randomly placed on a forested landscape consisting of 13,000 tiles.

4.3.5 Results

Output parameters were recorded at the end of every year. Modeling results are presented in box-and-whisker plots. Median, quartiles, minimum and maximum values were calculated for 10 year intervals. For each time interval, the whiskers indicate minimum and maximum values, the top and bottom of the box show the 1st and 3rd quartile, and the bold horizontal line bisecting the box locates the median observation value. Figure 4.6 shows the number of active mills over the course of the simulation.

For most simulation runs, the industry structure reaches equilibrium with four active mills, with a minimum of one and a maximum of nine active mills. These observations show a tight clustering around the median, identifying this as the most likely industry size given the current model size and specification. Industry consolidation mainly occurs over a 110 year period between years 21 and 130 of the simulation. The majority of mill insolvencies was observed between years 41 and 60. These insolvencies are closely linked to the average production cost structure of the industry (Fig. 4.7).

These production cost values allocate both fixed and variable costs to the realized production volume. Over the course of the 200 year simulation horizon, median production costs fall by 28 % from 129 $/mbf to 92 $/mbf. The distribution of production costs also changes over the course of the simulation horizon. During the first two decades, production costs are distributed in an almost symmetrical bell curve. As the simulation progresses, the cost distribution becomes increasingly skewed towards the minimum value of 88 $/mbf. Outliers in the 3rd, 15th, and 16th decade are caused by low capacity utilization levels in mills that are facing cash flow constraints. Low capacity utilization allocates a relatively large share of a mills fixed costs to each unit of output. The overall downward trend in production costs is driven by two processes. First, intensive cost competition

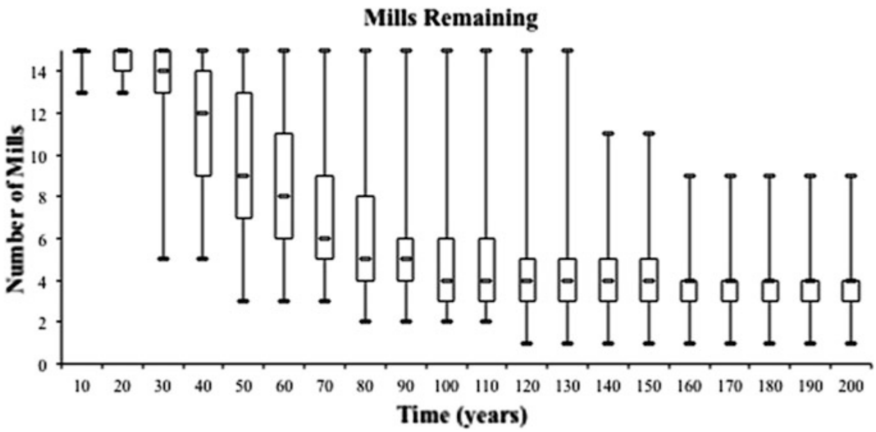

Fig. 4.6 Number of active mills remaining

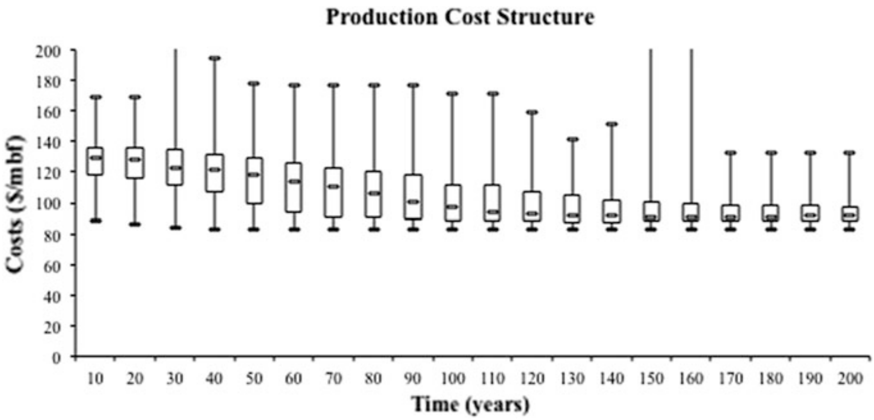

Fig. 4.7 Average production costs

occurs throughout each simulation run, with high-cost producers becoming insolvent as they are being undercut in the market. Second, mills with a high level of innovation potential are able to lower their production costs through investments in process innovation. The effect of these investments in innovation can be seen when comparing industry cost structure (Fig. 4.7) to the frequency with which specific strategies are being chosen (Fig. 4.8).

Choice frequencies show a very high degree of variability due to the strong influence of agent interaction on choice probabilities and the large number of choices that are being made in the simulation within a decade. The increasing skewedness of production cost values from year 50 onwards coincides with an increase from 10 to 33 % in the median relative frequency with which the innovation strategy is chosen. The temporary decline in choice frequency for the innovation strategy between years 20 and 70 can also be observed for the endogenous growth strategy.

In contrast to the sustainment strategy, both innovation and endogenous growth require investments beyond the capital requirements for periodic equipment replacement. Therefore, sustainment becomes the dominant strategy during the industry shakeout that occurs between years 20 and 70. During this period, capital reserves and existing production cost advantages are the most important factors in determining which mills are capable of outlasting their competitors. On average, this shakeout phase eliminates 75 % of the competitors and redistributes their market share among the remaining mills (Fig. 4.9).

The Herfindahl–Hirschman Index (HHI) reflects both the number and the relative size of firms active in a specific market. As shown in Fig. 4.10, industry concentration mainly occurs between years 40 and 110 of the simulation. This period of increasing HHI only partially overlaps with high rates of insolvencies (Fig. 4.6). Industry concentration is therefore not only caused by redistributing market shares as mills become insolvent. Especially during the later stage of the concentration process, from years 70 onwards, strategic choices become an

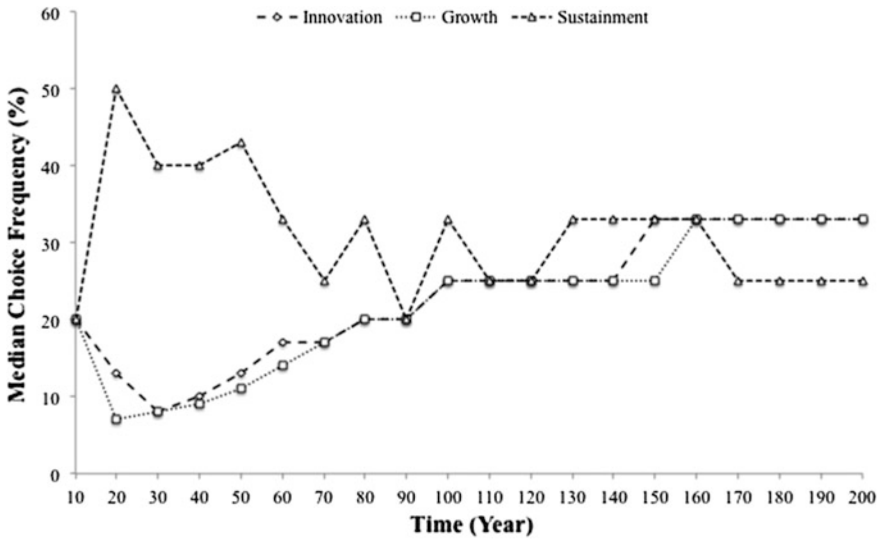

Fig. 4.8 Median strategy choice frequency over time

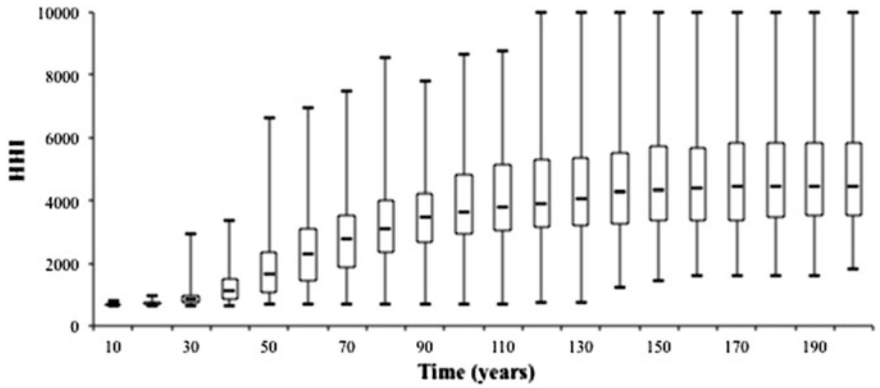

Fig. 4.9 Herfindahl-Hirschman Index (HHI)

important factor in size differentiation among the remaining mills. Individual mills emerge as dominant large-capacity producers while the remainder of the market is occupied by smaller profitable producers. Since mills are able to make suboptimal decisions it is not possible to establish a direct causal link between mill characteristics and their ability to become a dominant player.

The industry structure that emerges during these simulation runs is the result of agent interaction within the boundaries defined by both the underlying resource inventory and the lumber market. Using a 120 year rotation with a maximum volume of 500 m^3/ha, the maximum sustainable yield for the model area is

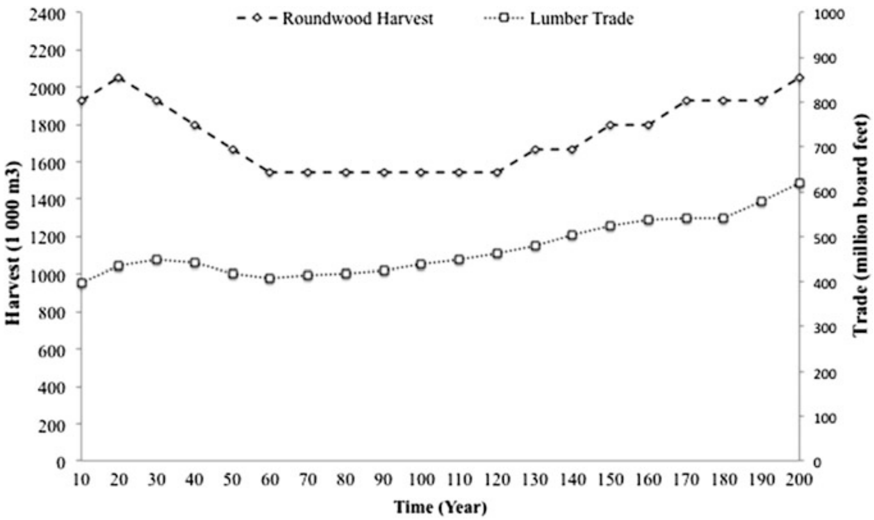

Fig. 4.10 Median roundwood harvest and lumber trade volumes

12.8 million m^3/year. The highest observed roundwood harvest was 4.5 million m^3/year, or approximately one third of the maximum sustainable harvest. This underutilization of available resources indicates that under current model settings market demand is acting as the limiting factor. The median annual volumes of roundwood harvested and lumber traded are shown in Fig. 4.10.

Over the first 80 years of the simulation, the 50 % of the observations occur within a narrow band between 360,000–460,000 mbf/year. This clearly defined peak disappears during the subsequent years, resulting in an almost uniform distribution at the end of the simulation horizon. A similar pattern can be observed for the distribution of lumber prices over time (Fig. 4.12).

The median values for lumber prices are a horizontal mirror image of the corresponding values in the traded volume graph (Fig. 4.10). This close tracking between volumes and price suggests that trades are occurring on the market demand curve, and that mills are successful in adjusting profit expectations to changing market conditions. While lumber prices remain relatively flat during the first 70 years of the simulation, stumpage rates increase by more than 40 % from 37 \$/m^3 to 52 \$/m^3 (Fig. 4.11). At the same time, the median annual harvest volume declines from 1.9 to 1.5 million m^3 (Fig. 4.10).

Combining these observations on market price, traded volume, stumpage rates, and roundwood harvest with information on industry cost structure (Fig. 4.7) provides an indication of the distribution of market power between the forest products industry and the owner of the timber inventory. Over the first 70 years of the simulation mills are getting more efficient, producing a stable volume of lumber from a decreasing amount of roundwood. Lumber prices remain stable, and mills realize a substantial reduction in their production costs. However, mills are

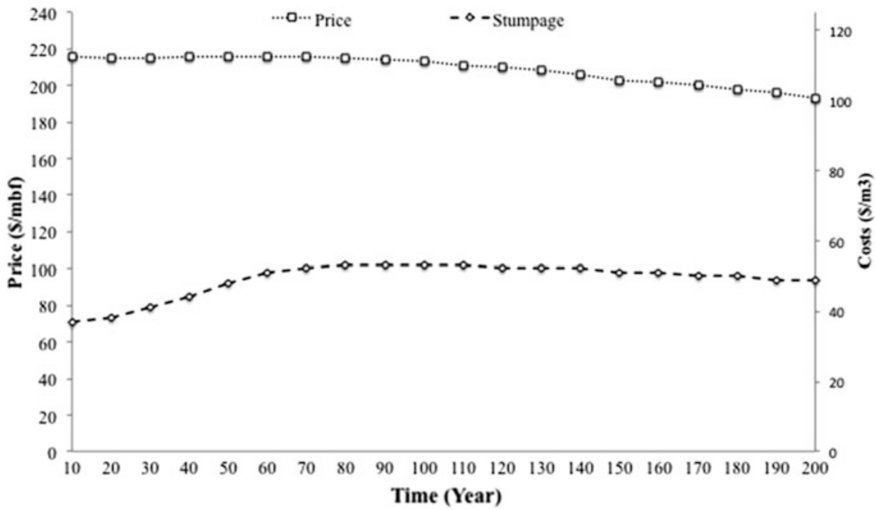

Fig. 4.11 Median market price and stumpage costs

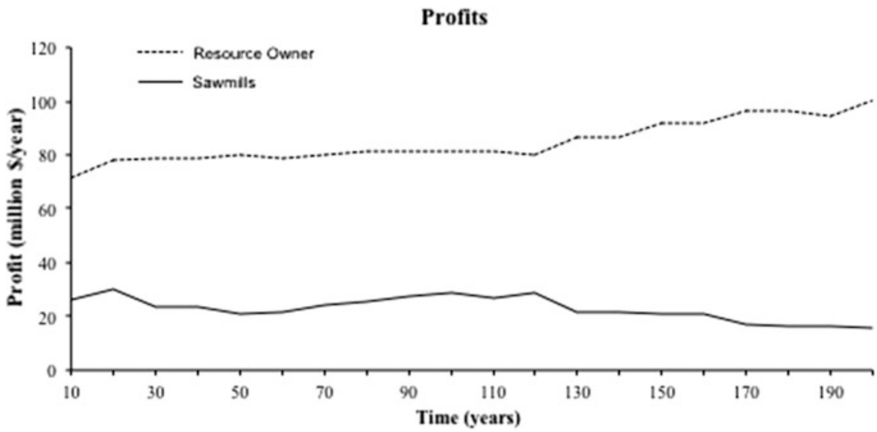

Fig. 4.12 Profit allocation between resource owner and sawmills

not able to capture the full value of these efficiency gains due to the competitive bidding process that is being used in determining stumpage rates. Profit allocation between sawmills and the resource owner is shown in Fig. 4.12.

The profit values in Fig. 4.12 are based on median values for production costs, harvest volume, stumpage, and traded volume. Over the first 20 years of the simulation, average expenditures on stumpage increase by almost 10 million $/year and remain steady at this new level. Forest industry profits only increase by about 4 million $/year before entering a prolonged slump. Since the number of active firms continues to decrease, the total profit per firm remains almost constant.

Median roundwood harvest and traded lumber volumes increase from year 120 onwards (Fig. 4.10). While stumpage rates decrease by 3 $/m^3, total profits accruing to the resource owner increase by approximately 25 % to 100 million $/year. The reduction in stumpage rates is not large enough to compensate for falling lumber prices, and processing sector profits decline by almost 45 % over the final 80 years of the simulation.

4.4 Conclusion

In the Cambium model, a specific industry structure is the result of exogenous and endogenous factors. Exogenous factors include parameters like consumer demand for specific products, the available supply of raw material and in the case of oligopolistic or perfectly competitive producers to a large extent the market price. Endogenous factors are defined within the model and include feedback from interactions with other agents, probabilistic processes within the model and each firm's competitive position and production costs. Systems approaches such as agent-based modeling are uniquely suited for exploring how phenomena such as a specific industry structure emerge. The emphasis on autonomously interacting agents allows for a departure from a purely mechanistic world view that has historically characterized the majority of quantitative studies (Vanderburg 1985).

At the current stage of development, the CAMBIUM model provides a useful framework for studying industry interactions and strategic decision making in an environment that is characterized by continuously changing conditions in both the underlying resource inventory and finished product markets. The modular setup of the model allows for further developments and adaptations of this model to specific research questions. Potential areas of research include studying the effects of unbalanced age class structures, product differentiation for dimensional lumber products, the inclusion of quality indicators in growth and yield modeling, further differentiation of business strategy options, and the introduction of different manufacturing technology choices. Identifying functional relationships would make it possible to more closely calibrate this model to specific regional industries and assess the performance of potential industry configurations.

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Chapter 5
Forest Management and Landowners' Discount Rates in the Southern United States

Stibniati S. Atmadja and Erin O. Sills

Abstract In theory, decisions with long-term pay-offs, such as whether to invest in forest management, are influenced by time preferences. However, this relationship is difficult to test empirically and time preferences are often assumed constant across individuals. We examine the relationship between forest management behavior and personal discount rates by modeling forest management choices as a function of individual discount rates elicited through binary choice questions. We focus on "limited resource woodland owners" in the Southern United States, including landowners who are traditionally underserved by public institutions (i.e., minorities and women) and who face financial, social and natural resource constraints that limit their forest management options. We found that the probability of harvesting timber is positively related with personal discount rates, as predicted by theory. However, discount rates are not significantly related to stand improvements or contact with a professional forester, suggesting that lack of investment in forest management is not a result of landowner impatience. Rather, these behaviors are driven by characteristics such as size of property, proximity of residence to woodlands, and tenureship characteristics including whether the woodlands are inherited.

S. S. Atmadja (✉)
Forests and Livelihoods Program, Center for International Forestry Research (CIFOR), Jalan CIFOR, Situ Gede, Bogor Barat 16115, Indonesia
e-mail: s.atmadja@cgiar.org

E. O. Sills
Department of Forestry and Environmental Resources, North Carolina State University, Raleigh, NC 27695-8008, USA
e-mail: sills@ncsu.edu

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5.1 Introduction

Nearly 25 % of private forestland in the US South is in the hands of families who own less than 100 acres each, and more than 90 % of private forestland owners in the region own less than 100 acres (Butler and Leatherberry 2004). A long line of research on family and other non-industrial private forest (NIPF) landowners has shown that they are a heterogeneous group and that their forest management decisions are driven by a more complex set of factors than simple profit-maximization from timber (e.g. Newman and Wear 1993; Kline et al. 2000; Conway et al. 2003; Vokoun et al. 2006). This study examines the factors underlying the forest management decisions of a particular group of family landowners: traditionally underserved and limited resource woodland owners (LRWOs).[1] By definition, these landowners face significant constraints that limit their forest management options. However, it is also commonly believed that their time preferences—specifically, high discount rates or short time horizons—inhibit investments in forest management. Despite this common belief and anecdotal evidence, most economic frameworks and analysis assume the same discount rate for all actors (typically a constant exponential rate). In this chapter, we test whether time preferences vary across forest owners, identify covariates of personal discount rates, and examine whether they are a significant driver of decisions to undertake stand improvements, seek advice from a professional forester, and harvest timber.

We focus on landowners who are traditionally underserved by public institutions (i.e., minorities and women) and who face financial, social and natural resource constraints that limit their forest management options. These LRWOs are commonly believed to have systematically different preferences and behavioral outcomes than the broader population of NIPF owners. Yet, they have been overlooked by most previous research, partly because of the difficulty of identifying and contacting them. This study overcame this obstacle with a novel sampling approach based on digitized land parcel and census maps.

Most studies of forest management do not explicitly include landowners' time preferences as an explanatory variable, even though forest management is an inherently long-term investment activity that requires landowners to make intertemporal choices. This could be due to the assumption that discount rates affecting

[1] We refer to this group as "woodland" owners rather than "forestland" owners, because they generally recognize and refer to their properties as having "woods" rather than "forest", which can have connotations of industrial timber management.

decision-making in forestry are determined by external factors that are related to the opportunity cost of capital and that do not vary across individuals within the same financial market. However, many studies have shown that forestry decisions by NIPF and family forest owners are driven by non-market values (e.g. bequest, aesthetic and environmental values), suggesting that heterogeneous personal discount rates should matter (Kant 1999). In the broader economics literature, there is evidence that personal discount rates vary across individuals, e.g. some studies have suggested that they are higher among poor, less educated, or minority individuals (Lawrance 1991). These same characteristics also can constrain forest management through other channels such as limiting access to information, and financial/technical assistance. As a result, the same observed outcome, such as lack of investment in forest management, may be caused by high discount rates or by lack of access to credit and cost-share programs such as the Forest Development Program in NC or the federal Environmental Quality Incentives Program. The challenge is to separate the effects of landowner characteristics on management decisions through time preferences from their effects through other channels.

We address this problem by employing a two-step procedure: (1) estimate the discount rate by modeling responses to a question about trade-offs across time as a function of landowner characteristics that have been hypothesized to influence time preferences; and (2) use the estimated discount rates to explain differences in behavior across landowners, controlling for landowner constraints that have been hypothesized to influence behavior. Results from this 'Structural' model are compared with results from a 'Reduced Form' model, which directly includes determinants of the discount rate in the behavioral model.

Separating the effects of time preference from other landowner characteristics, as done in the Structural model, can have important policy implications. For example, if poor landowners have low discount rates, they are patient enough to wait for the long-term benefits of forestry investments, but they may not have access to the capital required to undertake the investment. In this case, cost-share programs would be beneficial. If instead they have high discount rates, they would be unwilling to wait for the long-term benefits, regardless of the availability of cost-share. In this case, cost-share programs would miss the point: these landowners need viable short-term revenue streams from their woodlands. Finally, it is also possible that if other constraints are currently limiting, time preferences may not have an observable influence on behavior.

The following section reviews theories of heterogenous time preferences and the literature on time preferences among NIPF owners in the US, forest management behaviors of interest, and key constraints facing landowners. Section 5.3 describes methods of data collection and discount rate elicitation, and provides some descriptive statistics. Section 5.4 presents the utility-maximization model that links time preferences and resource constraints with forest management effort. Section 5.5 explains our approach to estimation, and Sect. 5.6 presents the results. Section 5.7 synthesizes results and concludes the chapter.

5.2 Literature Review

5.2.1 Determinants of Individual Time Preference

Four leading theories of heterogeneous time preferences are: (1) Endogenous time preferences (ETP) (Becker and Mulligan 1997); (2) Natural selection (Rogers 1994); (3) Primary vs. secondary needs (Moseley 2001); and (4) Comparative marginal utility (Loewenstein and Prelec 1992; Trostel and Taylor 2001).

In *ETP* theory, individuals can choose to invest resources (time, money, and energy) in goods and activities that increase the 'nearness', and hence the value, of future pleasures. Education is a common example. Factors that increase the expected value of future pleasures (such as having children) or the amount of currently available resources (such as income) will prompt decision-makers to invest more in items or actions that reduce their discount rates. These investments accumulate over time, tending to reduce the discount rate with age. This is off-set by the decline in future years of life remaining (and hence the expected value of utility from the future) with age. Hence age is expected to have a u-shaped relationship with the discount rate.

"Natural selection" theory views time preferences as a function of the survival probabilities of one's genes. Some altruism towards one's descendants and 'future self' at the expense of one's own current welfare is preferred because it ensures the survival of a species (Hamilton 1964a, b; Rogers 1994). According to this theory, discount rates vary with fertility and therefore with age, and also depend on whether or not one has descendants.

The "Primary vs. secondary needs" theory divides consumption between primary goods (non-substitutable, needed now) that are highly discounted, and secondary goods that are less urgently needed and therefore less heavily discounted. Overall discount rates depend on the relative budget share of each type of good. Thus, households who spend more of their budget on primary needs (such as food) are expected to have a higher discount rate.

"Comparative marginal utility" theory views time preference in the context of utility improvements compared to a baseline condition. For example, someone earning \$100/month is more likely to wait (have a lower discount rate) for a \$50 gift in one month compared to a person who earns \$5,000/month. This theory suggests that wealth and income affect discount rates by influencing baseline conditions. Table 5.1 summarizes theoretical predictions about how individual traits affect discount rates.

Atmadja (2008) reviewed 25 empirical studies linking individual traits to discount rates, applying a vote-counting approach to summarize findings. Household size and minority status tend to increase discount rates, while being female and well-educated tend to reduce discount rates. However, there are also numerous studies that have found these factors not significantly related with discount rates. Results for income, wealth and age are even more disparate, showing relatively equal support for negative, positive and no relationship with discount rates.

Table 5.1 Hypothesized effects on discount rate according to different theories

Discount rate factors	Endogenous time preference	Natural selection	Primary versus secondary needs	Marginal utilities
Income	(+)		(−)	(+)
Wealth	(−)			(+)
Household size			(+)	(+)
Number of children	(−)			
Gender		Effect depends on age/fertility		
Age	U-shaped	Effect depends on gender		(+)
Education	(−)			

Thus, the relationship between individual traits and personal discount rates appears to vary across settings and populations, and remains an open empirical question.

5.2.2 Time Preferences Among NIPF Landowners

Only a few studies have estimated discount rates of NIPF owners. Two studies were based on stated preference methods, where landowners were asked directly about their discount rates, and one study was based on observed behavior. The stated preference studies cast the discount rate in terms of the hurdle rate, which is the minimum rate of return that an individual would find acceptable for a particular investment scenario. The average (nominal) hurdle rates from studies in Mississippi (Bullard et al. 2002) and North Carolina (Kronrad and De Steiguer 1983) are 15 and 13 % respectively. Both of these studies find landowners with higher incomes have higher hurdle rates. They attribute this to the higher opportunity cost of capital among high-income landowners. Other landowner attributes, such as age and acres owned, were not found to be related to the hurdle rate.

In these studies, landowners were asked to state their hurdle rates in open-ended questions. For example, Bullard et al. (2002) asked respondents "What is the lowest interest rate you consider acceptable for a timberland investment" lasting 5, 15, and 25 years. And "What is the lowest interest rate you consider acceptable" for a savings account, stocks/bonds or certificate of deposit. Such open-ended questions are difficult for those who have limited knowledge of investing. Binary choice questions are more often used in other fields of economics to elicit respondents' discount rates (e.g. Kirby and Petry 2004; Harrison et al. 2002). In this broader literature, income is often found to be negatively related to discount rates, i.e. richer individuals have lower discount rates (Lawrance 1991; Agee and Crocker 1996; Poulos and Whittington 2000). These differing results may be due to the context in which time preference is measured. Hurdle rates are typically used to assess the opportunity cost of investment, which may be higher among richer individuals who have more investment options. Bullard et al. (2002) also find that hurdle rates increase with length of investment, possibly due to an increasing uncertainty premium with time or variation in discount rates over different time horizons, e.g. hyperbolic discounting, as discussed in Kirby and Marakovic (1995) and Vuchinich and Simpson (1998).

Prestemon and Wear (2000) estimated discount rates from observed harvesting behavior. Using Forest Inventory Analysis (FIA) data from two periods, they deduced discount rates for landowners who harvested their timber between the two surveys. The discount rate was estimated by assuming that landowners harvest if the expected value of future timber income is growing at a slower rate than their discount rate. The resulting (real) discount rate for NIPF landowners was 18 % per year, much higher than found for non-NIPF landowners in their study (2 % per year) and higher than the nominal hurdle rates found in the two stated preference studies.

As predicted by the classic Faustmann (1849) and Hartman (1976) rules for optimal rotation age, there is empirical evidence that interest rates affect harvesting and timber supply behavior. For example, Bolkesjø and Solberg (2003) and Kuuluvainen and Tahvonen (1999) found that bank loan interest rates increased short term roundwood supply. There is also a large body of research on the harvesting behavior of NIPF landowners (Vokoun et al. 2006). However, we are not aware of any prior studies that have analyzed the impact of landowners' *personal* discount rates on their timber harvest decisions.

5.2.3 Landowner Constraints and Behavior

Landowner characteristics interact with forest characteristics such as property size to determine the breadth of options available to woodland owners. Three common constraints on LRWO management decisions are: (1) small woodland acreage; (2) traditionally underserved status; and (3) unclear tenureship.

5.2.3.1 Woodland Acreage

Economies of scale in forestry limit the commercial viability of managing small woodlands for timber. Per acre costs of land preparation and planting are generally higher on tracts of less than 100 acres (Londo and Grebner 2004). Researchers have consistently found that management decisions are influenced by property size, as summarized in Table 5.2 (See also Alig et al. 1990; Vokoun et al. 2006). In general, owners of small woodland properties are less likely to undertake any activities with upfront costs, and there is mixed evidence on their use of forestry assistance. Timber harvest is likely to be less profitable on small landholdings, as larger acreage is associated with lower harvesting costs.

Table 5.2 Correlation between woodland acreage and forest management

	Behavior/ preference	Correlation with acreage	Reference and notes
Management activities	Management intensity	(+)	Webster and Stoltenberg (1959), Straka et al. (1984)
	Harvest Probability	(+)	Straka et al. (1984), Bliss and Grassl (1987), Alig et al. (1990), Cleaves and Bennett (1995), and Gan and Kebede (2005)
	Probability of timber sales	(+)	Hickman (1984)
	Government program participation	(+)	Thompson and Jones (1981), Ernst and Marsinko (1983), Nagubadi et al. (1996), Gan and Kebede (2005)
	Seeking Forestry Assistance	Mixed	Zhang and Mehmood (2001): Small landowners more likely to seek assistance for tree planting; Gan and Kebede (2005): No correlation; Melfi et al. (1997): Small landowners more likely to be served by public foresters
Costs	Timber bid price per acre	(−)/(0)	Hensyl (2005): harvested acreage negatively affects per-acre bid price up to 50 acres, but has no effect beyond 50 acres
	Cost of production/ac	(−)	Cubbage (1982), and Cubbage and Harris (1986)
	Access to credit	(+)	Binswanger and Sillers (1983)

5.2.3.2 The Traditionally Underserved

The USDA Forest Service defines the "traditionally underserved" as underserved customers, populations or communities including minority and low income landowners (USDA Forest Service 2000, pp. 33–34). This study adopts the broader definition used by the Agricultural Credit Improvement Act of 1992 (H.R.4906), which also includes women.

Female, low income, and minority landowners have been found less likely to seek government assistance (Zhang and Mehmood 2001; Gan and Kebede 2005). When they have only small tracts of woodland, this tendency is reinforced by economies of scale in arranging for forestry assistance (and in general, in learning about forestry). Even though landowners with small properties are mostly served by public foresters, who work for the county or state and provide limited free service (Zhang 1996), there are still significant costs in terms of the time and effort required to meet these foresters, who are spread thinly and work with many landowners. Further, LRWOs often are not part of the same social or professional network as either public or private consulting foresters, and are more often hindered by low literacy (Mance et al. 2004).

The ability of landowners to assess their options and make decisions is determined by the information they can access. In our survey, 27 % of LRWOs stated that the most challenging aspect of woodland management is that they do not know what to do with their woodlands. Better forestry knowledge may lead to more investment in management (Bullard et al. 2002) and higher revenues from timber sales (e.g. Alig et al. 1990; Munn and Rucker 1994; Hubbard and Abt 1989).

5.2.3.3 Tenureship

Many LRWOs own their land as heir property, a form of shared ownership. Shared ownership can make it difficult to agree on the management objectives and activities for a property, assign rights and responsibilities (such as paying property taxes), and arrange and divide the proceeds of timber harvests (Deaton et al. 2009). Legal options to avoid shared ownership, such as a written will, are less accessible to the poor (Land Loss Prevention Project 2008) and to minority landowners, who have faced a history of legal discrimination and therefore are reluctant to engage with the legal system (Thomas et al. 2004; Mitchell 2001). At the other end of the spectrum, sole owners face the fewest complications in decision-making about forest management.

5.3 Conceptual Framework

We draw on previous economic literature on NIPFs to frame the analysis of landowners' forest management behavior using a non-separable household production model of commercial forest products and forest amenities. This nonseparable, altruistic framework has been used extensively to study the forest management behavior of NIPFs (e.g. Conway et al. 2003; Amacher et al. 2002b). The basic premise of the model is that NIPF owners manage their woodlands for many reasons in addition to timber profit (Alig et al. 1990). As a result, forest and landowner characteristics and management objectives unrelated to timber profits play a significant role in determining harvesting and forest management behavior (e.g. Bliss and Martin 1988; Conway et al. 2003).

5.3.1 Model Description

The decision to invest in forest management is determined by the (current) cost and perceived (future) benefits of a healthier, more productive forest. The interplay between the landowner's preferences (e.g. management objectives, discount rate) and constraints affect the decision. Thus, the probability of undertaking management can be modeled as a function of the landowner's personal and household characteristics (e.g. age, gender, race, education, income, distance to woodland, level of forestry knowledge), and woodland characteristics (woodland size, tenureship arrangement; see Deaton et al. (2009)). In addition, because forest management is a long-term process involving long time horizons, management decisions are influenced by landowners' time preferences.

Consider a landowner who maximizes utility (U) from two periods within her lifetime.[2] Utility is a function of consumption of market goods (C) and environmental amenities (N), and is influenced by landowner characteristics (Z). For example, tenure status, which affects how forest amenities and income are shared and bequeathed, is part of Z. Utility in period 2 is discounted to period 1 by the discount rate (r), which is assumed constant.

$$U = U_1[C_1, N_1; Z] + \left(\frac{1}{1+r}\right) \cdot U_2[C_2,\ N_2; Z]$$

In this model, we assume that the discount rate r is a function of personal characteristics (Z_r)

$$r = r(Z_r) \tag{5.1}$$

The landowner determines the amount of timber harvest and forest management effort in both periods. Standing timber provides environmental amenities, while harvested timber provides income. Any unharvested woodlands in period 2 will be bequeathed to the landowner's descendants. Hence, deciding on the amount of unharvested woodlands in period 2 is equivalent to deciding on intergenerational non-timber amenities and timber income (Conway et al. 2003). This two-period model modifies the altruistic model of Conway et al. (2003) by explicitly taking into account forest management effort. Thus, utility is maximized with respect to the following constraints

$$C_1 = P \cdot H(X_1, E_1; Z) - O_1(E_1; Z) - S_1 + M_1 \tag{5.2a}$$

$$C_2 = P \cdot H(K - X_1 - Q_2, E_2; Z) - O_2(E_2; Z) + (1 + R)S_1 + M_2 \tag{5.2b}$$

$$N_1 = N_1(K - X_1, E_1; Z) \tag{5.2c}$$

$$N_2 = N_2(Q_2, E_2; Z) \tag{5.2d}$$

where P = timber price, H = volume of timber harvested, X = woodland acres harvested, E = effort (e.g. purchased inputs, searching for information), O = cost/outlay per acre from various forestry investments, S = savings, M = exogenous income, Q = standing timberland at the end of the period, R = market rate of interest that applies to savings, and K = initial woodland endowment. Subscripts 1 and 2 indicate the time period. The landowner's bequests consist of woodlands (Q_2). The real (undiscounted) value of savings grows at a market rate of interest R.

[2] The model can be expanded to consider bequest factors, which in turn would be influenced by tenure status (e.g., with uncertainty about future benefits introduced by heir property status).

Note that acreage harvested in the first and second time periods are $X_1 = K - Q_1$ and $X_2 = Q_1 - Q_2$, where K is the initial woodland endowment. In this study, we are particularly interested in the terms E_1 and r.

Interest and discount rates are assumed to be non-negative: $R \geq 0$; $r > 0$. If we assume a perfect labor market (i.e. time and money are perfectly tradeable), the time constraint can be collapsed into the budget constraint (Eq. 5.2a–b).

Substituting constraints into the utility function we derive the following Lagrangean function:

$$\begin{aligned} L &= U_1[C_1, N_1; Z] + \lambda_{N1}(N_1 - N_1(K - X_1, E_1)) \\ &\quad + \lambda_{C1}(C_1 - P \cdot H(X_1,\ E_1; Z) + O_1(E_1; Z) + S - M_1) \\ &\quad + \frac{1}{1+r} \cdot (U_2[C_2, N_2; Z] + \lambda_{N2}(N_2 - N_2(Q_2, E_2)) \\ &\quad + \left(\frac{1}{1+r}\right) \cdot \lambda_{C2}(C_2 - P \cdot H(K - X_1 - Q_2, E_2) + O_2(E_2; Z) - (1+R)S - M) \end{aligned} \tag{5.3}$$

The landowner maximizes utility with respect to C_1, C_2, X_1, E_1, S, Q_2 and E_2. The following conditions apply to marginal values for:
forest amenities:

$$\frac{\partial U_1}{\partial N_1} > 0, \frac{\partial^2 U_1}{\partial N_1^2} < 0; \frac{\partial U_2}{\partial N_2} > 0, \frac{\partial^2 U_2}{{}_2^2} < 0;$$

forest management effort:

$$\frac{\partial N_1}{\partial E_1} > 0, \frac{\partial^2 N_1}{\partial E_1^2} < 0; \frac{\partial O_1}{\partial E_1} > 0, \frac{\partial^2 O_1}{\partial E_1^2} > 0; \quad \frac{\partial H}{\partial E_1} > 0, \frac{\partial^2 H_1}{\partial E_1^2} < 0;$$

and woodland left in period 2:

$$\frac{\partial N_2}{\partial Q_2} > 0, \frac{\partial^2 N_2}{\partial Q_2^2} < 0; \frac{\partial H}{\partial Q_2} < 0, \frac{\partial^2 H_2}{\partial Q_2^2} < 0;$$

5.3.2 First Order Conditions

Taking first order conditions,[3] the following equation defines the optimal level of forest management effort in period 1:

[3] The complete first order conditions are displayed in Appendix A.1.

$$\underbrace{\frac{\partial U_1}{\partial N_1}\cdot\frac{\partial N_1}{\partial E_1}}_{A>0}=\underbrace{\left(\frac{\partial O}{\partial E_1}-P\cdot\frac{\partial H}{\partial E_1}\right)}_{B}\underbrace{\frac{\left(\frac{\partial U_2}{\partial N_2}\cdot\frac{\partial N_2}{\partial Q_2}\right)}{P\cdot\partial H/\partial Q_2}}_{C<0}\underbrace{\frac{(1+R)}{(1+r)}}_{D>0} \tag{5.4}$$

Equation 5.4 consists of four parts, which we label A, B, C and D. A is the marginal utility from management effort, via increases in forest amenities; B is the marginal utility from timber income, as influenced by forest management effort; C is the marginal rate of substitution between the utility from forest amenities from more forest being left in period 2 (Q_2), and the marginal timber income lost from foregoing the harvest of Q_2; and D discounts B and C into period 1. Hence, Eq. 5.4 captures the balance between forest management effort, harvesting, utility from timber income and utility from forest amenities. Since $A > 0$, $C < 0$ and $D > 0$, then it follows that $B < 0$. This implies that the level of effort is set such that the marginal cost of E_1 is lower than its marginal revenue, which means that the optimum level of E_1 is set below the level that would maximize timber profits. Figure 5.1 illustrates this point (See point E_1^1). The profit-maximizing level is reached when $A = 0$, i.e. when forest management effort does not affect amenity values, or when the marginal rate of substitution between timber income and amenities is zero (i.e. they are separate goods).

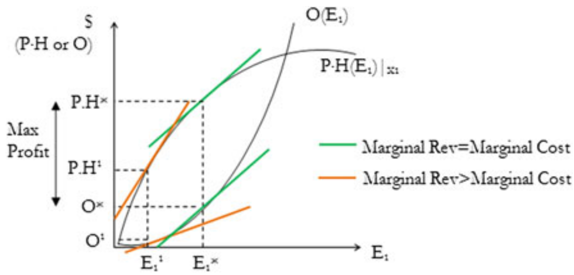

Fig. 5.1 Relationship between forest management effort (E_1), forest revenues ($P \cdot H$) and costs (O)

5.3.3 Comparative Statics

Equation 5.4 is re-arranged to aid interpretation of the comparative statics of this model:

$$\underbrace{\frac{\overbrace{\frac{\partial U_1}{\partial N_1}\cdot\frac{\partial N_1}{\partial E_1}}^{A>0}}{\frac{\partial O}{\partial E_1}-P\cdot\frac{\partial H}{\partial E_1}}}_{B<0}=\underbrace{\frac{\left(\frac{\partial U_2}{\partial N_2}\cdot\frac{\partial N_2}{\partial Q_2}\right)}{P\cdot\partial H/\partial Q_2}}_{C<0}\underbrace{\frac{(1+R)}{(1+r)}}_{D>0} \tag{5.5}$$

The left hand side (A and B) is the marginal rate of substitution between the marginal utility from forest amenities and the marginal utility from timber income. This is the shadow price of forest management effort. The right hand side (C and D) is the shadow price of consumption from period 1 (See Eqs. A.6 and A.7 in the Appendix A.1), which is the value of foregone timber income from period 1, saved into period 2. If the landowner decides to increase the amount set aside in period 1 Q_1 [given the same amount of land being harvested in period 2 (X_2)], the landowner would have more forest to enjoy and then bequeath in the second period (Q_2). Since B depicts the shadow price of Q_2 (the marginal substitution between higher utility from timber amenities and foregone timber income from setting aside forest land) and Q_2 depicts the foregone income/consumption from period 1 (X_1), B is then the shadow price of income/consumption. Since consumption is cast as foregone savings, term C takes the market rate of interest and discount rates into account.

The optimal level of management effort depends on the landowner's understanding of the effect of effort on outcomes that she cares about, such as forest amenities and timber production costs and revenues. All else constant, landowners who have a high marginal utility of forest amenities ($\uparrow \partial U_1/\partial N_1$) are likely to invest more in behavior to increase the level of forest amenities ($\downarrow \partial N_1/\partial E_1$). Those who have higher marginal utility from forest income ($\uparrow \partial U_1/\partial C_1$) such as poorer households, are more likely to invest in activities that increase timber revenues ($\downarrow P \cdot \partial H/\partial E_1$). If the same activity increases amenities but decreases timber income, landowners base their decision on the relative values of forest amenities and timber income (i.e. the ratio of A and B). If $A/|B| > 1$, they are more willing to trade-off income for amenities.

For activities that contribute to all goals (e.g. seeking technical advice from a forester), landowners base their decision on the cost of the effort itself ($O(E_1)$), which reduces utility by diverting income from consumption goods. The right hand side of Eq. 5.5 represents the shadow price of consumption from period 1, in terms of savings foregone. If more effort in period 1 results in more income in period 1, this money can be saved into period 2 and earn the market rate of interest, adjusted by the discount rate ($(1 + R)/(1 + r)$). Hence, higher R and lower r will increase savings.

The shadow price of money saved (or income earned in period 1) also depends on the area of forest that was harvested in period 1 to earn that money. More harvests in period 1 (X_1) leads to less forestland to set aside in period 2 (Q_2). Landowners who value forest amenities ($\uparrow \partial U_2/\partial N_2$) are more likely to set aside forests in period 2 ($\downarrow \partial N_2/\partial Q_2$). However, since more set-aside mean less harvests, this would reduce the amount of timber revenue. If the timber is high-value ($\uparrow \partial H/\partial Q_2$), it is more costly to set aside.

This conceptual framework guides the choice of explanatory variables to model forest management behavior, as summarized in Table 5.3.

Table 5.3 Empirical measures of factors identified in conceptual model

Factor in conceptual model	Empirical measure/proxy
Discount rates	Estimated using landowner characteristics and responses to survey questions
Market rate of interest	Assumed uniform in study area
Marginal utility of timber income	Income, education, occupation
Marginal utility of forest amenity	Distance to woodlands, frequency of visits to woodland, opinion of importance of protecting nature, inheritance status, sole vs. shared ownership, distance from woodland
Marginal utility from forest amenities	Opinion on importance of protecting nature
(Perceived) Marginal effect of forest management on amenities and timber income	Access to information (traditionally underserved status), woodland acreage

5.4 Study Description

5.4.1 Data Collection

Data were collected in 2003 via a mail survey of family forest landowners in seven counties in North Carolina (Duplin, Halifax, Northampton, Robeson, Sampson, Warren) and Virginia (Brunswick), as highlighted in Fig. 5.2. These counties have high proportions of minority-owned and operated farmlands and of woodlands on farmlands (USDA-NASS 2002), and considerable amounts of NIPF land (Sills and Warren 2002).

The sampling frame was based on two criteria: (1) Landownership: own more than 5 acres of woodland in at least one parcel in at least one study county, but less than 100 acres of total land (including non-woodland) across the seven study counties; (2) Demographic: at least one parcel of woodlands is located in a census tract with high percentage minority population, low median income, *and* low educational attainment, relative to the county median values.

To construct this sampling frame, we combined geo-referenced data on real estate from each county's tax assessor office with census tract data from the US Census Bureau. Absentee landowners and owners of small properties were over-sampled due to concerns about potential low response rates. Thus, in each county, we contacted at least 12 absentee landowners, and at least 12 landowners who owned less than 30 acres of woodland or total land. The rest of the sample was randomly selected from the list of LRWOs, as defined by the landownership and demographic criteria, which also included some absentee and small woodland owners.

We mailed 1,179 survey packets in July 2004,[4] with 175 surveys sent to each study county, with the exception of Halifax, where we sent packets to all 129

[4] The survey instrument was pretested and reviewed by woodland owners, forestry faculty at NCSU, and forestry extension agents to ensure that the questions were easy to understand yet

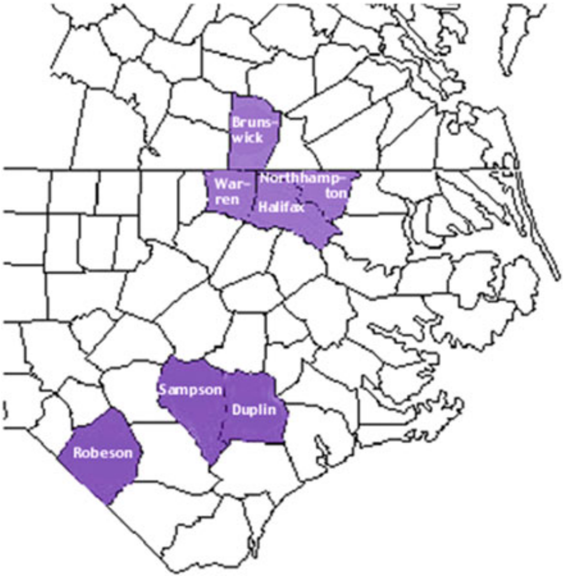

Fig. 5.2 Map of study counties

landowners who met our criteria. A total of 84 questionnaires were returned and discarded due to inaccurate address information. Of the 303 respondents, 4 were eliminated from the sample because they no longer owned woodlands. Thus, there are 299 valid observations, for a 27 % response rate. The questionnaire consisted of 55 questions on land ownership, woodland characteristics, forest management experience and opinions, time preference, and sociodemographic characteristics. The text was designed to accommodate people with limited literacy skills and forestry knowledge.[5]

5.4.2 Descriptive Statistics

Table 5.4 displays descriptive statistics for survey respondents and compares these to results from the National Woodland Owner's Survey/NWOS (Butler 2008). The NWOS sampled landowners across the state, by picking sampling points in a grid,

(Footnote 4 continued)
presented forestry concepts accurately. Information about the survey was published in local newsletters a month before the survey took place. Landowners selected for the survey were sent postcards to inform them they were being requested to participate. This mailing was followed by a survey packet that included a cover letter, survey booklet, request for survey results, pre-addressed postage paid envelope, and small gifts (e.g. a refrigerator magnet with the study logo, $1 bill, mini cd-rom with forestry information). A month afterwards, landowners who had not replied were sent follow-up postcard reminders.

[5] More details on the study are available from www.ncsu.edu/woodland.

Table 5.4 Respondent characteristics

Characteristics		Percentage/levels		
		This study	2006 NWOS survey[a]	2000 US census (NC)[b]
Woodland acreage				
Total acres owned (mean/median)		161ac/50ac		
Total woodland acres (mean/median)		74ac/30ac	Median < 9ac	
# woodland parcels(mean/median)		2.3/2	Median: 2	
Percent with characteristics of traditionally underserved landowners				
Income		38 % (<$45,000)	34 % (<$45,669[c])	Median $44,371[c]
Education	Up to high school	30 %	46 %	25 %[d]
	High school diploma up to bachelors degree	39 %	30 %	21 %[d]
Race	African American	22 %	1 %	21.6 %
	White	69 %	96 %	72.1 %
	Native American	7 %	1 %	1.2 %
Gender: Female		37 %		51 %
Employment:	Retired	48 %	57 %	
	Full-time	31 %	41 %	79 %
Age (years)		Mean 63/Median 64	Median 55–64	>65: 12.0 %

[a] Butler (2008)
[b] US Decennial Census 2000 (US Census Bureau 2001a, 2001b). U.S. Census Bureau, Summary File 1 (SF 1) and Summary File 3 (SF 3) unless otherwise stated (Bureau 2001a, b)
[c] Equivalents in 2004 prices
[d] US Census Bureau (2004)

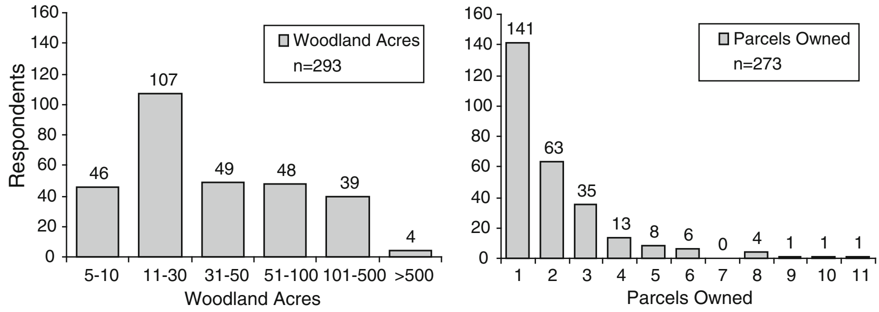

Fig. 5.3 Woodland ownership distribution among respondents

and contacting the landowners of points that were forested. There are two key differences in the population represented by these surveys: (1) NWOS included owners with 1–5 acres of woodland, which we excluded from our sample; and (2) the NWOS summary data are for the entire state, because the 2006 wave included only 321 landowners in NC, not allowing for reporting at the county level. Table 5.1 also includes figures for NC from the 2000 US Census, to represent the general population.

5.4.3 Woodland Acreage

The sampling frame was designed to target owners of less than 100 acres of woodland, since they represent more than 90 % of woodland owners in the South but are often underrepresented in studies of NIPF. In the final sample, most respondents (85 %) did own 100 acres or less of woodland.[6] These are mostly (87 %) held in one to three parcels of land (See Fig. 5.3).

5.4.4 The Traditionally Underserved

By targeting areas with high minority populations, we obtained a more varied racial composition in our sample than in previous NIPF surveys. African American and Native American woodland owners comprise 29 % of our respondents. In comparison, 15.1 % farm operators in the study counties were African American or Native American (USDA-NASS 2002). Almost half of respondents were

[6] There were several ways that landowners with more than 100 acres could have been included in our sampling frame. Most often, this happened because they own land outside the seven study counties. In some cases, they owned land under different names (e.g., as heir property) that were not linked in our sampling frame.

Table 5.5 Access and tenureship

Access and tenureship	This study (%)	2006 NWOS survey[a]
Live within 5 miles from woodland	50	n/a
Inherited some of their woodland	58	31 %
Tenureship		
Co-own with spouse	47	83 % (Sole and co-own with spouse)
Sole owner	32	

[a] Butler (2008)

retired, consistent with the observed median age of 64 years. Respondents were better educated than the average population. The NWOS results suggest that this is characteristic of family forest owners in general, although it could also be due to self-selection: better-educated individuals may feel more comfortable answering mail surveys.

5.4.5 Tenureship and Access

A high proportion of woodland owners inherited some part of their woodland. As displayed in Table 5.5, 79 % of respondents were co-owners of woodland with their spouse or were sole owners. The rest (21 %) share ownership with people other than their spouses, most commonly siblings sharing ownership of heir properties.

Many respondents live within 5 miles of their nearest woodland, and 40 % visit their woodlands at least once a month. Proximity to woodland is positively associated with the frequency of visits: half of those who live more than 10 miles away visit their woodlands less than once a year. However, living on the woodland property is no guarantee of frequent visits, since nearly 25 % of these landowners visit their woods only a few times a year.

5.4.6 Forest Management Behavior

Most respondents were engaged in managing their forests. One in three had sold timber in the past 10 years. This compares to approximately 40 % who reported receiving offers from timber buyers at least a few times a year. 41 % had made some stand improvements in the last 5 years, including site preparation, tree planting, prescribed burning, chemical applications, road/trail maintenance or construction, creating wildlife habitat/preserve, tree thinning, and hiring laborers. The most common activities were road maintenance/construction and tree planting, which were done in the past 5 years by 19 and 15 % of all respondents respectively. Only a quarter of respondents had been in contact with a professional forester in the past 5 years. This is consistent with other studies (e.g. Measells et al. 2005) that have found low rates of contact between woodland owners and professional foresters.

5.5 Methods

Our estimation strategy involves two-steps: (1) Estimate the discount rate, and (2) Model forest management behaviors as a function of the estimated discount rate and covariates. In the second step, three forest management behaviors are modeled as binary choices using the Logistic model. Because these models include a pre-estimated variable (the discount rate), standard errors for the coefficients are based on bootstrapping the model 1,000 times. In each round, the marginal effects of each variable are calculated for each observation and averaged. The coefficients and marginal effects reported are medians from the 1,000 bootstrapped models. Significance levels are determined as the percentile of zero in the 1,000 estimates of the coefficient. We report marginal effects (averaged across observations) only for the variables that have effects statistically different from zero at the 20 % confidence level.

In order to estimate the behavioral models, we first need to construct measures of forest management and of the discount rate, as described next.

5.5.1 Forest Management Behavior

We model the probabilities that respondents have (1) made stand improvements, (2) contacted a forester, and (3) harvested timber. The variables representing stand improvement and contact with a forester were constructed from the following questions:

In the past 5 years, have you:

Activity	*Yes*	*No*	*Don't know*
a. Been visited by a county forester (from the State Division or Department of Forestry)?	☐1	☐0	☐8
b. Hired a consulting forester to manage a timber sale or other activities?	☐1	☐0	☐8
c. Prepared land for planting new trees (site preparation)?	☐1	☐0	☐8
d. Planted trees (seeds or seedlings)?	☐1	☐0	☐8
e. Burned lightly on purpose (prescribed burning)?	☐1	☐0	☐8
f. Applied fertilizers, herbicides or pesticides?	☐1	☐0	☐8
g. Constructed or maintained roads, trails, fire lines?	☐1	☐0	☐8
h. Created wildlife habitat or a wildlife preserve?	☐1	☐0	☐8
i. Thinned or released trees?	☐1	☐0	☐8
j. Hired laborers to work on your woodland?	☐1	☐0	☐8

A respondent is considered to be engaged in stand improvement if she answered Yes at least once for questions c-j, and to have been in contact with a forester if she answered Yes at least once for questions a-b. Those who answered "Don't Know" or did not provide any answers were combined with those who answered "No".

A respondent is considered to have harvested timber if she answered yes to the following question:

Have you sold timber from your woods in the past 10 years?
☐0 No ☐1 Yes ☐8 I don't know

Consistent with the conceptual framework, previous literature, and focus on LRWO, the probability of engaging in each behavior is modeled as function of the variables listed in Table 5.6. For example, those who have inherited lands may attach different amenity values to their "homeplace" and higher importance to land bequests, and therefore may behave differently than other landowners.

The discount rate is expected to have a negative relationship with the probability of contacting foresters and investing in stand improvement, but a positive relationship with timber harvest, because high discount rates encourage landowners to harvest sooner and therefore more frequently. Both investing in the forest and working with a professional forester have current costs in terms of time and/or money but future benefits in terms of a higher quality forest for timber and/or amenities. Hence, it is expected that landowners with lower discount rates who put higher value on future benefits will be more likely to carry out these activities.

5.5.2 Discount Rate Estimation

We estimate discount rates using landowner characteristics and their answers to inter-temporal tradeoff questions in the survey. Respondents revealed their time preferences by answering two questions, which required them to choose between two timber harvesting options that occur at different interval lengths and provide different levels of income (See Appendix A.2). Respondents were presented with the following scenario "Suppose that you are given 50 acres of woodland about a mile away from your house. This woodland has a mixture of pines and hardwoods and a mixture of different size trees. A forester takes a look at this woodland and gives you two choices".

The survey elicited their preference between these two hypothetical choices, which always included (a) Larger Seldom (LS) payments, where large timber income is received now and every 32 years; or (b) Smaller Frequent (SF) payments, where a smaller timber income is received now and every 8 years. The income received (P_{LS} and P_{SF}) varies across questions and respondents. There is also an opt-out option for respondents who choose 'Neither'. This question was designed to elicit preferences regarding timber management (even vs. uneven age) and time preferences specific to decisions about woodlands.

The amount of the payments in the LS and SF options (P_{LS} and P_{FS}) varies across the two questions and across respondents. For each version of the question, there is an implied discount rate (ρ) that makes the present value of both options equal, which is obtained by solving Eq. 5.5:

Table 5.6 Hypothesized determinants of forest management behavior

Factors	Parameter	Description	Expected signs		
			Improve stand	Contact forester	Timber harvest
a	Estimated discount rate	Estimated from landowner characteristics and responses	(−)	(−)	(+)
a	Children	Number of children	?	?	?
a	Age	Age	?	?	?
b	Income	Dummy variable: income >$45,000	(+)	(?)	(?)
b	Education	Dummy variable for respondents with ≥4 year Bachelor's degree	(+)	(+)	(+)
b	Occupation: retired	Dummy variable for respondents who are retired	(−)	?	?
c	Inheritance	Dummy variable for respondents who inherited at least some of their woodlands	?	?	(+)
c	Tenure: sole owner	Dummy variable for respondents who are sole owners of at least some of their woodlands	?	?	?
c	Tenure: with spouse	Dummy variable for respondents who co-own at least some of their woodlands with their spouses	?	?	?
c	Distance to woodland	Dummy variable for respondents who live ≤5 miles from woodland	(+)	(+)	?
c	Woodland visits	Dummy variable: visits woodlands at least once a month	(+)	(+)	(+)
c	Importance of forest amenities	Dummy variable: thinks that protecting nature is very important reason to own woodlands	(−)	(+)	(−)
d	Gender: female	Dummy variable for female respondents	(−)	(−)	(−)
d	Race: African American	Dummy variable for African American respondents	(−)	(−)	
d	Woodland acreage	Total woodland owned in the 7 study counties	(+)	(+)	(+)

[a] Discount rates and Z_R. Variables such as gender, household size, income and race were excluded from the model of discount rates because they were statistically insignificant and their inclusion would have contributed to multicollinearity problems in second stage
[b] Marginal utility of timber income
[c] Marginal utility of forest amenity
[d] (Perceived) Marginal effect of forest management on amenities and timber income

$$\frac{P_{LS,q}}{P_{SF,q}} = \frac{1 - e^{-\rho t_{SF}}}{1 - e^{-\rho t_{LS}}} \tag{5.5}$$

There were 22 combinations of P_{LS} and P_{SF} used in the survey that result in implied rates ranging from −0.3 to 25.1 % per year. If a respondent chooses LS (SF), her personal discount rate is higher (lower) than ρ. Because there are two such questions, it is possible to construct bounds on each landowner's discount rate. The implied rate of the first question is always lower than the second question.

Those who switched from choosing LS in the first question ($r > \rho_{Low}$) to SF in the second question ($r \leq \rho_{High}$) provided an upper and lower bound for their discount rate, which is ideal for some estimation methods, but not necessary for others. The opposite choice behavior (SF in response to first question and LS in response to second question) is inconsistent because the discount rate has no defined range. There were only seven inconsistent responses, which were excluded from further analyses. Respondents who always chose one option, or who did not answer one of the questions, provide only an upper or lower bound.

We estimate the discount rate using the Grouped MLE method, which assumes respondents answer the two questions by comparing their discount rates (known to themselves but not the analyst) to implicit discount rates that would make the present value of the LS and SF response options equal. We model their choice as a function of respondent characteristics and a stochastic term, as in Eq. 5.6:

$$r_j = \beta \cdot Z_{r,j} + \varepsilon_j \tag{5.6}$$

Where β is a vector of K coefficients for a vector of landowner characteristics that affect the discount rate (Z_r), and ε is the error term, which is assumed to be log normal.[7] The literature on time preferences reviewed above suggests that Z includes variables such as age, gender, race, household size, number of children, education and income. However, because Eq. 5.6 serves primarily to predict a personal discount rate as an explanatory variable for the second stage regression of forest management behaviors, we exclude variables that are statistically insignificant from Z in order to reduce multi-collinearity in the second stage. When only the upper (ρ_{High}) or lower (ρ_{Low}) bound of the discount rate is observed, the dependent variable is left or right-censored.

Drawing on Cameron's (1988) insight that survival models could be estimated for dichotomous choice contingent valuation data, we estimate the following equation using the LIFEREG procedure in SAS:

$$(\rho_{Low,j}, \rho_{High,j}) = \sum_{k=1}^{K} \beta_k \cdot Z_{r,k,j} + \varepsilon_j \tag{5.7}$$

The predicted discount rates are unique for each vector of explanatory variables, Z_r. As Barton and Mourato (2003) point out, the β vector can be interpreted as the marginal effects of the explanatory variables on the expected discount rate for each respondent.

[7] The discount rate is assumed to follow a log-normal distribution for two reasons: (1) estimates from this distribution were within observed discount rate ranges for 70 % of the respondents, which is a higher proportion compared to results based on normal or Weibull (extreme value) distributions; and (2) the log-normal distribution limits the estimates to be non-negative, which is supported by the time preference literature (e.g. Olson and Bailey 1981).

5.6 Results

5.6.1 Discount Rate Estimation

The Grouped MLE method results in unique discount rate estimates for all combinations of the explanatory variables that define different subgroups of the population. We first estimated the model with all variables suggested by the conceptual framework, including gender, minority status, education, household size, age, number of children, and income indicator, and then dropped variables that were statistically insignificant. With interaction terms, the combination of age, children, and income results in unique discount rate estimates for nearly every respondent. Based on the estimation results in Table 5.7, the average discount rate for all respondents is 2.63 %, ranging from 0.01 to 7.2 % per year.

The marginal effect of children on discount rates is positive for respondents with less than three children, zero for those with three children, and negative for those with more than three children. Since 87 % of respondents have three children or fewer, the effect of the number of children on discount rates is generally positive. The discount rate increases with age, but this trend is tempered by income. Respondents with higher income have higher discount rates but they increase at a slower rate as they age, compared to those with lower income.

A high percentage of respondents always choose LS or SF (59.6 %) or only answered one of the two discount rate elicitation questions (11.7 %), resulting in censored observations (i.e. only the upper or lower bounds of their discount rates are known). A minority (10 %) had bounded discount rates. The remainder did not provide valid responses, because either they did not answer any questions or they provided inconsistent answers. Similar results have been obtained in other binary choice surveys that elicit time preferences (e.g. Pender 1996; see summary in Atmadja 2008). This pattern of response constrains our ability to accurately estimate personal discount rates. We therefore view the results as indicative of the magnitude of discount rates in the population we study but not as precise estimates of discount rates for use in net present value calculations. The more important results are the relationships between personal characteristics and discount rates.

Table 5.7 Discount rate estimation

Parameter	Estimate	Pr > ChiSq	Mean
Intercept	−8.3105***	<0.0001	
Age	0.0535**	0.0456	63.02
Age * Income >$45,000	−0.0797**	0.0263	29.52
Children	0.7021***	0.0795	2.01
Children^2	−0.1271*	0.0891	6.07
Income >$45,000	5.6587**	0.0169	0.5
Pseudo R-Square	0.027		

Significance level: * (10 %), ** (5 %), *** (1 %)
Dependent variable: upper and lower bounds of discount rate. $N = 242$

Variables that were used to estimate the discount rate (age, income, number of children) could also conceivably affect forest management behavior directly. As discussed next, we did not include these in the structural versions of the behavioral models due to concerns about multicollinearity in our fairly small sample.[8] The role of time preferences vs. other landowner and property characteristics could be more clearly identified by eliciting discount rates in large-sample surveys.

5.6.2 Models of Forest Management Behavior

The three forest management behaviors are modeled as binary choices using the Logistic model. Reduced form models use all of the explanatory variables identified in the conceptual model as potential determinants of forest management behavior, without imposing any particular structure on how these variables are related with each other. The 'structural' model replaces the variables in the reduced form model that explain the discount rate with the estimated discount rate. The signs and significance of coefficients on the other variables are generally similar across the two modeling approaches (Table 5.8).

Female respondents are less likely to be in contact with professional foresters, which is consistent with anecdotal evidence such as the attendance profiles at outreach meetings that were held by the research team. Landowners who have larger acreages are more likely to be in contact with professional foresters. Surprisingly, respondents who co-own land with their spouses are substantially less likely to be in contact with foresters compared to landowners who co-own with people other than their spouses. The discount rate is not significant in determining whether a landowner contacts a forester.

Tenureship plays a large role in shaping decisions about investing in woodlands. Forestry investments are less likely among respondents who co-own with family members, as compared to sole owners. Unlike co-ownership with a spouse, co-ownership with family members usually implies higher transactions cost, because for example, family members often live far away from each other and may find it difficult to act as a single decision-making unit. Indeed, those who are 'closer' to the land, in the sense that they visit it at least once a month, are substantially more likely to invest in their stands. Retirees are also less likely to invest, perhaps because (1) they do not have the physical ability to undertake forestry activities, or (2) they have fixed incomes that do not allow for large financial investments.

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[8] Environmental preferences are potentially correlated with time preferences and a determinant of forest management behavior, and therefore could potentially also introduce multi-collinearity into models of forest management as a function of time preferences. This is confirmed by a positive and statistically significant (*P*-value: 0.025) correlation between the estimated discount rate and respondents who put high importance on protecting nature. However, this variable does not have a statistically significant impact on any of the behaviors in multivariate models.

Table 5.8 Determinants of forest management behavior[a]

Parameters	Reduced form		Structural form	
	Estimate	Marg.Eff	Estimate	Marg. eff
(a) *Probability of contacting a forester*				
Intercept	0.4943		−1.5061**	
Estimated discount rate			0.3592	
Inherit woodland	0.4852		0.2786	
Tenure: sole owner	−0.0851		−0.0973	
Tenure: own w/spouse	−0.7788*	−0.1128	−0.6697†	−0.101
Education ≥ Bachelor degree	0.3098		0.229	
Retiree	0.2052		−0.0245	
Live within 5 miles of woodland	0.5316		0.5021	
Visit at least once/month	0.0258		0.0368	
Protecting nature is important reason for owning woodland	0.8738		0.6969	
Female	−0.7176**	−0.1021	−0.6403*	−0.097
African American	−0.3625		−0.2493	
Woodland acreage	0.0070***	0.001	0.0066***	0.001
Age	−0.0410*	−0.006		
Age * income	0.0323***	0.0047		
Income >$45,000	−2.315			
Number of children	0.7142**	0.1076		
Number of children^2	−0.1524**	−0.0236		
Median pseudo R-sq[b]	0.0854		0.0699	
(b) *Probability of investing in stand improvements*				
Intercept	−1.8287		−1.6570***	
Estimated discount rate			10.0194	
Inherit woodland	−0.2451		−0.3108	
Tenure: sole owner	0.9327**	0.1703	0.9318**	0.1748
Tenure: own w/spouse	0.7570†	0.1299	0.7680†	0.143
Education ≥ Bachelor degree	0.1517		0.1307	
Retiree	−0.6021†	−0.1141	−0.6199*	−0.1146
Live within 5 miles of woodland	0.0387		0.0559	
Visit at least once/month	0.9891***	0.1876	0.9743***	0.1822
Protecting nature is important reason for owning woodland	−0.4455		0.0737	
Female	−0.1784		−0.1525	
African American	−0.3306		−0.2975	
Woodland Acreage	0.0062***	0.0011	0.0062***	0.0012
Age	0.974			
Age * Income	0			
Income >$45,000	0.692			
Number of children	0.294			
Number of children^2	0.418			
Median pseudo R-sq[b]	0.109399		0.116899	

(continued)

Table 5.8 (continued)

Parameters	Reduced form		Structural form	
	Estimate	Marg.Eff	Estimate	Marg. eff
(c) *Probability of harvesting timber in the last 10 years*				
Intercept	−2.7705*		−2.6426***	
Estimated discount rate			19.5339*	3.6843
Inherit woodland	1.1557***	0.2053	1.0293***	0.1915
Tenure: sole owner	−0.2103		−0.1945	
Tenure: own w/spouse	0.5388		0.5893	
Education ≥ Bachelor degree	0.2729		0.2515	
Retiree	0.0205		−0.3145	
Live within 5 miles of woodland	0.5298		0.4822	
Visit at least once/month	−0.5379†	−0.091	−0.4598	
Protecting nature is important reason for owning woodland	−0.4296		−0.4754	
Female	0.1537		0.1829	
African American	0.414		0.4396	
Woodland Acreage	0.0099***	0.0017	0.0095***	0.0017
Age	−0.0011			
Age * Income	−0.0421***	−0.0076		
Income >$45,000	2.8411			
Number of children	0.4512			
Number of children^2	−0.0999*	−0.0173		
Median pseudo R-sq[b]	0.10593		0.104025	

Significance level: * (10 %), ** (5 %), *** (1 %), † (15 %),

[a] All models were bootstrapped 1,000 times to account for pre-estimation of discount rate

[b] Median Pseudo R-Square is calculated based on the median log likelihood of the behavioral models with intercept only ($LLog_0$) and with covariates ($LLog_1$) across the 1,000 models estimated for bootstrapping, using the formula: $(LLog_0 - LLog_1)/LLog_0$)

The positive and significant coefficient on woodland acreage shows that owners of larger woodlands more actively invest in their woodlands compared to owners of smaller woodlands. They may have more at stake, for example in preventing fires or the spread of diseases, be in a better position to take advantage of the economies of scale in forestry, or have more varied land resources that give them more management options. Again, the discount rate is not statistically significant in this model. One possible explanation is that different types of forest activities (e.g. site preparation, creating wildlife habitat) have different relationships with the discount rate.

Higher discount rates lead to a higher probability of a respondent having harvested her timber in the past 10 years. This is as expected, since discount rates increase the opportunity cost of growing (as opposed to harvesting) timber and thus decrease the rotation age. Those who own more woodland acreage and inherited at least part of their woodlands are substantially more likely to have harvested timber. Aside from acreage, other characteristics associated with limited

Table 5.9 Discount rate as sole explanatory variable of behavior

Parameter	Contact forester		Stand improvements		Timber harvest	
	Estimate	*P* value	Estimate	*P* value	Estimate	*P* value
Intercept	−1.212***	0.000	−0.571***	0.008	−1.1571	0.000
Est. Discount Rate	5.349	0.514	8.365	0.324	23.692***	0.006

Significance level: [*] (10 %), [**] (5 %), [***] (1 %), [†] (15 %),
[a] Median estimate from bootstrapping 1,000 times; *P* value was derived non-parametrically

resource ownership, such as gender, race and education, and a preference for protecting nature, are not significant determinants of timber harvesting.

The overall model fit as indicated by the pseudo-R^2 measure is only marginally better in the reduced models, which include as covariates all of the factors used to estimate the discount rate (i.e. age, income and children). The low explanatory power suggests that there is either some inherent variability in these decisions or some important explanatory factors that we did not elicit through the survey. For example, idiosyncratic factors such as whether a logger happens to find a landowner at home, or whether a forester happens to attend the same church as a landowner, could be key determinants of timber harvesting and stand improvements.

Table 5.9 presents estimation results for models that include only the discount rate with no covariates. The signs and statistical significance of the coefficients on the estimated discount rate remain the same, confirming that it has no direct impact on the probability of engaging a professional forester or engaging in forest management, but it has the expected impact on harvesting behavior.

5.7 Conclusions

Our study of personal discount rates and their relationship with forest management provides insights into forest landowners' choices, including how they are likely to respond to forest management incentives and regulations. First, age and income interact so landowners with higher incomes have higher discount rates that decrease as they age. This contradicts the common perception that poorer people have shorter time horizons or higher discount rates (cf., Kant 1999). Several theories of time preference suggest that discount rates are positively correlated with age: as we grow older, we become more impatient, because the expected utility of future consumption falls as physical abilities decline with age (e.g. Trostel and Taylor 2001). We found this to be the case only for low-income individuals. Those with higher incomes have declining discount rates as they age, which is also theoretically valid, considering the effect of experiences (e.g. Becker and Mulligan 1997) and utility from inter-generational altruism (e.g. Rogers 1994). We did not find any evidence of the non-linear relationship with age predicted by some other theories of time preference.

Second, we found the expected positive relationship between discount rates and timber harvest. However, discount rates were not significantly related to stand improvements or contact with a professional forester, suggesting that lack of investment in forest management is not a result of landowner impatience. Rather, these behaviors are strongly driven by characteristics such as size of property, proximity of residence to woodlands, and tenureship including whether the woodlands are inherited.

Third, after controlling for other factors, we did not find any evidence that race affects forest management behavior, but women have a lower probability of contacting foresters, all else equal.

Fourth, sole and spousal woodland owners are more likely to invest in their woods compared to owners with other tenureship arrangements. Owners of inherited land are less likely to invest in timber stand improvements. Both of these findings may be the result of management challenges associated with heir property status and the lack of feasible legal remedies to reverse this status, as recognized by the Uniform Law Commission (2011).

Fifth, the results of this study provide some support for programs that reduce up-front costs of forest management, such as state or federal cost-share programs. Discount rates of landowners are low and have little impact on forest management decisions other than harvest. Thus, high discount rates (or impatience) are not likely to constrain the effectiveness of cost-share in promoting investment in forest management.

Sixth, there are other non-financial barriers to forest investment, such as lack of information. Many respondents indicated that the most challenging aspect of forest management is just 'knowing what to do'. Forestry information has been traditionally disseminated to landowners via landowner organizations and public meetings, where participants are typically white male landowners. Women and owners of small woodland properties are less likely to receive or to seek forestry assistance, according to our survey results. Putting more resources into outreach to these populations, as well as to elderly and retired woodland owners, could be a fruitful long-term public investment.

Finally, most landowners chose harvesting options that provide relatively small revenues accrued at shorter intervals than the typical timber rotation. Atmadja (2008) finds that this reflects a preference for more even revenue flows as well as the discount rates of respondents. Especially in the context of increasing forest fragmentation (De Coster 1998), more effort is needed to develop and disseminate forest management alternatives (e.g. silvicultural techniques, harvest of non-timber forest products) that can provide these more even income streams, as well as technology and services that are appropriate for owners of small woodlands.

Appendix

A.1 First Order Conditions

Re-stating the Lagrangean function (from Eq. 5.3)

$$\begin{aligned} L =& U_1[C_1, N_1; Z] + \lambda_{N1}(N_1 - N_1(K - X_1, E_1)) \\ &+ \lambda_{C1}(C_1 - P \cdot H(X_1, E_1) + O_1(E_1) + S - M_1) \\ &+ \frac{1}{1+r} \cdot (U_2[C_2, N_2; Z] + \lambda_{N2}(N_2 - N_2(Q_2, E_2))) \\ &+ \left(\frac{1}{1+r}\right) \cdot \lambda_{C2}(C_2 - P \cdot H(K - X_1 - Q_2, E_2) + O_2(E_2) - (1+R)S - M) \end{aligned} \tag{A.1}$$

Maximize Eq. A.1 with respect to C_1, C_2, N_1, N_2, X_1, E_1, E_2, S, and Q_2

$$\frac{\partial L}{\partial C_1} = \frac{\partial U_1}{\partial C_1} + \lambda_{C1} = 0 \rightarrow \lambda_{C1} = -\frac{\partial U_1}{\partial C_1}$$

$$\frac{\partial L}{\partial C_2} = \frac{\partial U_2}{\partial C_2} + \lambda_{C2} = 0 \rightarrow \lambda_{C2} = -\frac{\partial U_2}{\partial C_2}$$

$$\frac{\partial L}{\partial N_1} = \frac{\partial U_1}{\partial N_1} + \lambda_{N1} = 0 \rightarrow \lambda_{N1} = -\frac{\partial U_1}{\partial N_1} \tag{A.2}$$

$$\frac{\partial L}{\partial N_2} = \frac{\partial U_2}{\partial N_2} + \lambda_{N2} = 0 \rightarrow \lambda_{N2} = -\frac{\partial U_2}{\partial N_2} \tag{A.3}$$

$$\frac{\partial L}{\partial S} = \lambda_{C1} - \lambda_{C2}\frac{(1+R)}{(1+r)} = 0 \rightarrow \lambda_{C2} = \frac{(1+r)}{(1+R)} \cdot \lambda_{C1} \tag{A.4}$$

$$\begin{aligned} \frac{\partial L}{\partial X_1} &= \lambda_{N1}\frac{\partial N_1}{\partial X_1} - \lambda_{C1}P\frac{\partial H}{\partial X_1} + \lambda_{C2}\left(\frac{1}{1+r}\right)P\frac{\partial H}{\partial X_1} = 0 \\ &\rightarrow \lambda_{N1}\frac{\partial N_1}{\partial X_1} + \lambda_{C2}\left(\frac{1}{1+r}\right)P\frac{\partial H}{\partial X_1} = \lambda_{C1}P\frac{\partial H}{\partial X_1} \end{aligned}$$

$$\frac{\partial L}{\partial E_1} = \lambda_{C1}\left(\frac{\partial O_1}{\partial E_1} - P \cdot \frac{\partial H}{\partial E_1}\right) - \lambda_{N1}\left(\frac{\partial N_1}{\partial E_1}\right) = 0 \tag{A.5}$$

$$\frac{\partial L}{\partial E_2} = \lambda_{C2}\left(\frac{\partial O_2}{\partial E_2} - P\frac{\partial H}{\partial E_2}\right) - \lambda_{N2}\frac{\partial N_2}{\partial E_2} = 0$$

$$\frac{\partial L}{\partial Q_2} = -\frac{\partial N_2}{\partial Q_2}\lambda_{N2} + P \cdot \frac{\partial H}{\partial Q_2} \cdot \lambda_{C2} = 0 \rightarrow \lambda_{C2} = \lambda_{N2}\frac{\partial N_2/\partial Q_2}{P \cdot \partial H/\partial Q_2} \tag{A.6}$$

Setting Eq. A.6 equal to Eq. A.4, we get:

$$\lambda_{N2}\frac{\partial N_2/\partial Q_2}{P\cdot\partial H/\partial Q_2}=\lambda_{C1}\frac{(1+r)}{\alpha(1+R)}\to\lambda_{C1}=\lambda_{N2}\frac{(1+R)}{(1+r)}\frac{\partial N_2/\partial Q_2}{P\cdot\partial H/\partial Q_2}\tag{A.7}$$

Substitute Eq. A.7 into Eq. A.5:

$$\lambda_{N2}\frac{(1+R)}{(1+r)}\frac{\partial N_2/\partial Q_2}{P\cdot\partial H/\partial Q_2}\left(\frac{\partial O}{\partial E_1}-P\cdot\frac{\partial H}{\partial E_1}\right)=\lambda_{N1}\left(\frac{\partial N_1}{\partial E_1}\right)\tag{A.8}$$

Substitute Eqs. A.2 and A.3 into Eq. A.8 and rearranging terms:

$$\frac{\partial U_1}{\partial N_1}\cdot\frac{\partial N_1}{\partial E_1}=\left(\frac{\partial O}{\partial E_1}-P\cdot\frac{\partial H}{\partial E_1}\right)\frac{\left(\frac{\partial U_2}{\partial N_2}\cdot\frac{\partial N_2}{\partial Q_2}\right)}{P\cdot\partial H/\partial Q_2}\frac{(1+R)}{(1+r)}\tag{A.9}$$

A.2 Survey Module for Eliciting Personal Discount Rates

Suppose that you are given 50 acres of woodland about a mile away from your house. This woodland has a mixture of pines and hardwoods and a mixture of different size trees. A forester takes a look at this woodland and gives you two choices: Choice A or Choice B.

(1)	*Choice A*	*Choice B*
	You cut and sell all of the trees now and replant with pine seedlings. You earn $(P^{32}_1) *per acre. Every 32 years, you cut and replant all of your trees and earn* $(P^{32}_1) *per acre. Your earnings already include all cos*t	You cut and sell some of the trees now and let them grow back on their own. You earn $(P^{8}_1) per acre. Every 8 years you cut some more trees and earn $(P^{8}_1) per acre. Your earnings already include all costs
	This choice gives you more money each time *you sell, but you wait longer between harvests*	*This choice gives you less money each time you sell, but you don't wait as long between harvests*

Which would you pick?

☐*1 Choice A*
☐*2 Choice B*
☐*3 Neither*

Now suppose that you end up with a different piece of woodland and the forester gives you the following two new choices: Choice A or Choice B.

(2) *Choice A*	*Choice B*
You cut and sell all of the trees now and replant with pine seedlings. You earn $(P^{32}_1) *per acre. Every 32 years, you cut and replant all of your trees and earn* $(P^{32}_1) *per acre. Your earnings already include all cost*s	You cut and sell some of the trees now and let them grow back on their own. You earn $(P^8_1) per acre. Every 8 years you cut some more trees and earn per $(P^8_1) acre. Your earnings already include all costs
This choice gives you more money each time you sell, but you wait longer between harvests	*This choice gives you less money each time you sell, but you don't wait as long between harvests*

Which would you pick?

☐*1 Choice A*
☐*2 Choice B*
☐*3 Neither*

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Chapter 6
Impatience, Inconsistency, and Institutions to Counter Their Effects on Sustainable Forest Management

Colin Price

Abstract Human impatience and the inconsistency between affective and cognitive views of "otherness" undermine the foundations of sustainable forest management. Modern economies have induced institutions that reinforce this tendency, including through academic institutions where apologists for discounting flourish. It was not always so. The ethos of societies and nations supported long-term productivity against short-term interest. Individualistic ethics also internalised long-term well-being within present mental constructs. Rapid change and imposition of unfamiliar codes threaten the stability of future-protective institutions. Local sustainability may be at the expense of sustainability elsewhere. Current models of self-interest have been projected as possessing intrinsic ethical merit. Justification of discounting by financial institutions is undermined by the institutions' actual performance. The law may accidentally assist sustainability by its universality. Commonality of interest is only efficacious for future interests if supported by a further ethical requirement, but our conforming with this requirement may encourage later generations to do so too. Some reinforcement of conscience-based behaviour may be derived from religion, mutual censure, art, academic integrity and pre-commitment, and by regarding sustainability as a present good. These seem frail motivations, but offer the best hope for future generations.

Keywords Conscience-based behaviour · Counter institutions · Democracy · Discounting · Impatience · Individualistic ethics · Institutions · Modern economies · Otherness · Sustainable forest management

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C. Price (✉)
90 Farrar Road, Bangor, Gwynedd LL57 2DU, UK
e-mail: eimprice@btinternet.com

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6.1 Prelude

Firstly, let us suppose that we know the answers to two related questions.

Suppose, secondly, that the prevailing institutions will not enact these answers.

Thirdly, let us ask: what revival of past institutions, reform of existing ones and what creation of new ones might achieve the desired outcomes, or at least provide a better approximation?

The two questions are: how should members of different generations be treated? and how, consequently, should the benefits of resources, as well as the burdens of a deteriorated environment, be distributed across generations?

Regarding the first question, there may be an ethical understanding that in principle all generations should have equal entitlement. This can be argued from many points of view; and the arguments that there are *not* obligations to future generations can generally be rejected (Ott 2006), on grounds of rationality and consistency, as well as intuitively. I take it as my starting point, that there is *no morally relevant difference* between generations, that could justify treating them differently. The *otherness* of future generations is not a morally relevant difference. This particularises the general answer given to questions of justice by western philosophers from Immanuel Kant to John Rawls. It was an answer of eastern philosophers and holy people long before that time. It is embedded in learned stewardship, as it is passed down in the oral history of forest-living nations (Clarkson et al. 1992): "the seventh generation" for whom the ecosystem's function is to be maintained, represents all potential beneficiaries whose birth will come after the lifetime of anyone presently living.

There is no fundamentally important message from the present doctrine of sustainability, none, other than this one.

But we do not act *as though* we have a belief of that kind: we squander resources on transient pleasures, and bequeath public liabilities in a way that no law of private inheritance could countenance. For, knowing our sentiments, and knowing what is right, are two different knowings. Adam Smith (1759) understood this distinction. He posed the following to the Britons of his day: suppose we compare an accident in which we lose our little finger, with a catastrophe in China in which hundreds of thousands of people lose their lives. Our sentiments are more concerned with our own loss: but that does not mean that, intellectually, we consider it more important than the catastrophe, or believe that avoiding the first, matters more than avoiding the second: what we feel instinctively is no guide to what we *understand* to be right.

In the context of time, we are moved by impatience to seek benefit for ourselves early rather than late. We do it in that process of discounting which is so central to forest economics. And yet what we do, instinctively, seems altogether hostile, intellectually, to the concept and practice of sustainable forest management. Because, in giving added weight to our own present, we give less weight to our own near-future—which near-future generations share with us. And directly, we give less weight to more-distant-future generations themselves, because of their *otherness*.

We give less weight to our future selves' well-being through inability or unwillingness to engage in anticipated retrospect: we fail to consider how decisions will look, with that wisdom of hindsight which in due course will be deployed by those seemingly other persons who are in fact our future selves. There live within us two persons: an *affective* doer, moved by the moment's impulse, and a *cognitive* planner, who is aware of the need to weigh and consider (Thaler and Shefrin 1981). We should be "interested in tomorrow's satisfaction as such, not in *today's assessment* of tomorrow's satisfaction" (Sen 1957, p. 746). But we are not as we should be. The default position is that the doer has the upper hand, simply because *decisions about who has the upper hand lie with the doer*. And it seems dreadfully probable that it will always remain so. There is no logic or justice in this ascendancy of the doer: it is just a product of evolutionary pressures for the individual to "seize the moment's advantage", which are now dysfunctional for survival of the species.

The existence of these two persons also leads to inconsistency of judgement. When we consider relative values in our own middle- and far-distant futures, we see both points in time as the planner sees them, because the present-orientated doer is not engaged in either future circumstance. But, when the middle-distant future becomes the present, it receives a premium in relation to that far-future which has now become middle-distant: decisions previously deemed optimal, for example on forest rotation length, are revised (Price 2011). This same inconsistency informs our intuitive judgement, that near-future generations should weigh their own interests at parity with those of far-future generations.

On the whole, the means by which forest economists have removed the inconsistency is by rationalising the discounting process, so that each period's lapse of time entails the same proportional loss of value. Yet this "solution" of the problem in fact worsens the outcome: the planner's balanced judgement is overruled, even for those future times to which the doer's impatience is not connected. Thus the value of the second and all subsequent forest rotations becomes, normally, only a small fraction of the value of the first rotation, although the latter's benefits lie in the middle-distant future, and the former's, in an almost equally valued far-distant future. This, more than anything, is what makes the viewpoint of forest economists so incomprehensible to other specialists within the forestry profession.

And, on this discounting basis, economists have collaborated in project appraisals which prefer exploitation to sustainable forest management; have underwritten destruction of soils and ecosystems; and been party—they still are—to compromising a tolerable global climate in the name of what is sometimes rather trivial advantage. Their recent, often reluctant commendation of lower discount rates (Stern 2006) still leaves dramatically reduced weight during the time period over which climate change becomes overwhelmingly important—and particularly the effect on it of increasing the area of sustainably managed forests.

6.2 Sustainable Forest Management in History

Things have not always been so.

Until the Industrial Revolution, communities managing forests had evolved rules in use that regulated not only exploitation by one individual at the expense of contemporaries, but also by one generation at the expense of later ones. Experience of the shortages consequent on over-harvesting embedded the lesson of sustainability as a prerequisite for communal survival. The more recent history of forest management, indeed, became strongly focused on the regulation of production, firstly by the allowable area, and then by the allowable volume that might be cut in one year, without compromising long-term productivity. Thus far, relatively formal management reflected traditional understandings of the forest: adopted life-modes are sustainable because, in a stable system, the consequences of stepping outside the limits are culturally known and are proscribed by the tradition (Clarkson et al. 1992).

When and where individualistic ethics and appropriated ownership overrode communities' power to act, the new dispensation also performed under a sustainability ethic: the forest, the estate, the entire owned resource, should be passed to the next generation, in as good a condition as that in which it was received from the previous one. The occasional spendthrift owner who dissipated the inheritance incurred the censure of contemporaries, who were acting, it seems, on behalf of the future. The personal cost of applying to others such arm's-length censure was inconsequential, requiring no direct expenditure or sacrifice of immediate income on one's own part. And yet this planner's judgement could be turned against oneself, should the temptation ever arise to follow the doer's dissipatory path. Continuity of ownership and continuity of community were vital to maintaining this benign mutual coercion.

Let us not, however, ascribe too much virtue, too readily, to our ancestors. Past generations did not destroy their resource base, partly because they lacked adequate means of exploitation: perhaps their technologies were not aggressive enough to extract from the soil more nutrient than natural processes replenished? And perhaps periodic famine and pestilence kept the population at a level that the forest could sustain.

When these things changed, forests were threatened.

Rapid change—of technology, of domicile—and imposition of unfamiliar codes are indeed what tend to undermine sustainable forest management and future-protective institutions. Stability allows the planner to exercise a beneficent even-handedness of judgement: the future is a facsimile of the present and its needs are easy to empathise with. In times of change, however, the doer is excited and empowered by prospects of immediate improvement, untrammelled by any experience of the ill-consequences of the new kind of actions. The planner's restraining viewpoint can be derided as mere conservatism, and a nebulous future is readily presented as competent to provide for its needs, without the patronising intervention of a benevolent but misguided present.

The lack of understanding of changed circumstances is only seen by observers detached from the change. With an hubris for which western economists should blush, Fisher (1930, pp. 375–376) observed that

> "among [the peoples subjugated in colonial expansion,] interest is high, that there is a tendency to run into debt and to dissipate rather than accumulate capital."
>
> He might also have noted that, previously, these disparaged populations had effectively and sustainably managed *physical* resources, which colonist populations tended to squander. Humans are evidently more successful in implementing *customary* rules which fit *customary* circumstances, and deal least competently with systems to which they have been least conditioned (Price 1993, pp. 113–114).

As the technology of cultivation, industrial production and transportation advanced, management of the woodlands on the UK's large private estates came under review. Mining of coal and expansion of trade to finance imports removed the need to supply physical products: an attractive living environment became the first objective of sustainable forest management. And often this amenity came to depend, for its continued support, on income imported from elsewhere, from places where physical and social sustainability were thereby threatened. In Jane Austen (1814) *Mansfield Park*, cosy domestic dramas revolve around the merits of naturalistic and formal layout of woodlands, and the morality of young people acting in plays of passion. But in the background lurks the source of supportive income in the plantations of the West Indies and the morality of humans' violations of each other. The officious Mrs Norris, the ineffectual Lady Bertram, the sanctimonious Sir William and the saccharine Fanny Price all owe the continuity of their life-background to a socially and ethically unsustainable slavery. And, while the *dramatis personae* consider the aesthetic arrangement of trees and the durability of matrimony, the authors of their wealth suffer injustice, indignity, injury and death. Their *otherness* disobliges the inhabitants of the parkland landscape from caring, or even thinking, about those life conditions. Their words are the words of champion moralisers: but their concerns are with themselves and with those who are like themselves. Fanny Price does ask Sir William about the slave trade. But the answer, if any, is not recorded.

The work of fiction reflects the reality of many a landed estate.

6.3 Learning for the Situation We Face

So, what institutions might help to commit ourselves to treating the far-future as *other-than-other*? And, more problematically, to bind near-future generations to maintaining that commitment? As we survey the possibilities, it may seem that modern polities have induced institutions that reinforce, rather than counter, the tendency to impatience.

Self-interest has become infused with believed intrinsic merit. Adam Smith name and advocacy of pursuing self-interest have been adopted by institutes whose narrow world view he would eloquently have repudiated. “There is no such thing as society,” a UK prime minister is reported as declaring (Thatcher 1987).

Academic institutions have proliferated, where apologists for the practice of discounting deploy these stylised arguments.

- Since the human race may not survive through many future generations, there is little point in reserving forest resources not-to-be-used, or in mitigating climate not-to-be-enjoyed—a recipe for self-fulfilling prophecy if ever there was one.
- The tastes of future generations may differ from ours: therefore we should give less weight to benefits accruing to future generations, since they may not regard them as benefits at all. While this makes some sense in relation to premiums due to conformity with current fashion, it is less persuasive in relation to the resources required to meet basic needs; and fashions recur, so that not all value due “merely” to taste is inexorably evanescent.
- Diminishing marginal utility seems to provide an intellectually respectable case for discounting. For example, Schelling (1999) cautions against spending the tax dollars of impoverished US citizens on mitigating climate change, because the beneficiaries will, mostly, be affluent citizens of (for example) Bangladesh in 50 or 100 years’ time—his argument, not mine. Such discounting particularly undermines the merit ascribed to forestry as an aid to sustaining a tolerable global climate because:
  - carbon fixing is spread over a whole rotation, and in the UK for example does not reach a maximum for 30–40 years even with fast growing crops;
  - the displacement of high-carbon-emissions structural materials mostly occurs at the rotation end;
  - following these effects, the earth’s thermal inertia causes a decades-long lag in the full climatic effect.
- Perhaps the greatest of the sophistries, is the fashionable advocacy of discounting at a declining rate through time (UK Treasury, undated; Price 2005), thus in effect if not intention phasing in an ethos less hostile to sustainability. This is known, not altogether helpfully, as hyperbolic discounting. But the process merely replicates the inconsistency between the planner’s judgement and the doer’s, favourable to short-term short-sightedness, but more amenable to long-term concerns.

6.4 Counter-Institutions: Banks et al.

Banks and other financial institutions, including those selling futures in resources, might seem an unlikely source of justice to future generations. They have never been in worse repute, so many having let down the present generation with promises of an undeliverable future. They are, however, part of the intellectual strand that has long purported to explain why discounting is compatible with sustainability. If natural resources such as forests yield a low rate of return (it is argued) future generations would attain greater well-being if we eliminated those resources, and invested the proceeds in the high-yielding modern economy. This is sustainable forest management only in the widest possible sense: and is recognisable as sustainability only in the weakest possible sense. The argument has a long history (Rostow 1956), with some forestry advocates (Westoby 1962).

A similar, more recent version of this argument (Parfit 1984) proposes that damage to future generations' well-being can be compensated by investing money at present: and, the more distant the requirement for compensation, the smaller need be the sum invested.

Validation of this argument depends firstly on whether such a compound growth of monies could in fact provide adequate compensation. Broome (1994) argues that, exactly because of the diminishing marginal utility of increasing income, more *money* will be required in the future to compensate for a given loss of *utility*. And the further into the future that the loss occurs, the greater will be the required monetary compensation. Thus, Broome states, equal investment will be required, irrespective of how far in the future the damage to interests occurs. (Actually, this is only so under unit elasticity of marginal utility of income.) Price (2000a, 2010) goes further, showing that under plausible assumptions no amount of compensation may, in due course, provide adequate compensation: whether that is for loss of deeply felt environmental values, or for fundamentals for survival. Hence discounting could be at a negative rate, eventually indefinitely so.

The validity of these arguments also hangs on investments' actually being made; and not only made, but maintained without depletions, through the lapse of time required to deliver compensation to the injured parties. The signs are not good for the effectiveness of the process. According to El Serafy (1989):

> setting aside part of the proceeds [of natural resource exploitation, say] for reinvestment is *only a metaphor* [my emphasis].

But metaphorical reinvestment provides sustainable resources and compensations only for metaphorical people. As d'Arge et al. (1982) succinctly put it:

> Economists often use the notion of "hypothetical" compensation to justify discounting. In an ethical context such arguments play no role whatsoever. Rather, if no actual compensation occurs, the market rate of return has no relevance for discount rates.

The reality of "take-off into self-sustained growth" has all too often been somewhat as follows. Revenues from forest exploitation, like those from other resource depletion, have not been reinvested in their entirety—or even, sometimes, at all. They have been repatriated by transnational companies. They have funded personal consumption by elites, or prestige investments with minimal development content, or competitive growth of military strength. They have been drawn down to counter the effects of resulting environmental damage. Instead of take-off into self-sustained growth, the aircraft of economic development has reached the end of the runway provided by natural resources, where it remains to this day, wheels entombed in the morass of international indebtedness.

Nor are the developed nations innocent of plundering their own resources, while using the justification of metaphorical reinvestment. The North Sea Oil revenues that were supposed, in the 1980s, to fund regeneration of the UK's manufacturing economy, were partly diverted to provide tax cuts, immediate growth of consumption, and an aid to getting the government re-elected. Under the same government, selling off the state-owned Forestry Commission at a time of tight public finance was proposed (a situation repeated in 2010). A physical resource that had taken 70 years to build up would have met the public sector borrowing requirement for, at most, a few days (Price 1994).

Countries that have achieved rapid economic development successfully have done it on the basis of borrowed, evolved and improved technology, not destruction of forest resources. South Korea, still heavily forested and now the 11th largest economy in the world, stands as an obvious example.

When the reinvestment required to justify discounting of resource revenues is *not* made, the failure is because of that very impatience which has also been used to justify discounting: one argument for discounting defeats the validity of another.

Nor does institutional reform seem likely to assure the requisite investment in the future's well-being. Banks, beleaguered as they have become by critics in the early years of the third millennium, are nonetheless clear on one point: they must be allowed to exercise their own commercial judgement about giving their customers what they want. Nor are stipulations expected or likely on how or—crucially—when, profits will be distributed to shareholders or lenders.

Historically, religions have placed limitations on charging interest or usury, particularly at exploitative rates. The Quran's prohibition of interest might be understood as a proscription against exploiting future people that may not have the means to repay, as the state of the deeply indebted nations now illustrates. This is the other side of the coin, because accumulation of interest means payment of interest, which is only possible if borrowing is used to finance physically productive enterprises—again, real investments, not metaphorical ones. High international interest rates are themselves product of rich nations' attempts to sustain consumption through economic downturns, by drawing investment funds from international markets rather than from internal sources (Miller 1991). Ironically, they make deforestation projects both *attractive* (because long-term costs are heavily discounted), and *necessary* (because some short-term means must be found of making the increased repayments).

Deuteronomy's proscription of interest is explicitly confined to co-religionists. Interest may be charged to *others*—those of other religions, and, in the nature of interest, of other generations.

Other scriptures appear more permissive. *The Laws of Manu* (Doniger and Smith 1991) defines the interest rates which are proper to charge, according to the borrower's caste. Those of higher caste are charged a lower rate, perhaps because they are less likely to default on repayment. But, in the perspective adopted above, the defaulting of concern is not only that of the borrower, but that of the lender, in failure to use accumulated interest in enterprises of real long-term productivity.

And, following that line, the Quran says that Allah forbids interest, but permits trade. One reading is this: trade is fair because both parties agree to it, which might, nominally, be presented as the case when logging takes place. But, in relation to resource-depleting transactions, how can the agreement of future generations be assumed or even expected, no just recompense to them having been paid or provided for?

Ng and Wills (2006) argue that the purchase of futures provides the vehicle for giving just attention to later generations' needs. It seems an optimistic expectation: futures will be purchased only when expected prices rise faster than the prevailing interest rate: that is, to meet much acuter scarcity than what is experienced presently. The motivation to mitigate the shortage problem in fact assumes that the problem will not be effectively mitigated.

6.5 Democracy

What of democratic government in the service of long-term interests? One cannot draw much confidence from Marglin's (1963) much-quoted assertion that:

> a democratic view of the state does not countenance governmental intervention on behalf of future generations.

And

> Governments … lie under the political desideratum of gaining quick results. To underwrite the interests of the future may incur the displeasure of the present electorate: only in exceptional times do promises of "blood, toil, sweat and tears" constitute a successful electoral slogan (Price 2006).

There is a prevailing misconception among environmental economists, that while consumers make purchases out of self-interest, as citizens they vote disinterestedly (Sagoff 1988). The more likely account is, that individuals face different choice sets according to whether they are purchasing consumers or voting citizens; but they act self-interestedly in either case (Price 2000b). It could be that, acting collectively, people are *less* impatient (Sen 1967), and maybe *more* consistent. But this does not abolish impatience and inconsistency entirely.

Perhaps, even now, governments are acting on global warming only because they mistakenly believe—or believe that their constituents believe—that present action will bring immediate alleviation of climate change problems. The present generation of forest scientists—and other scientists—is left with an ethical dilemma: should they maintain the "helpful" political and public illusion that swift results are possible; or displace it with a less efficacious truth that puts at hazard whatever good *has* been achieved? That truth is, that the results of present-day mitigating actions accrue only in the middle-distant future, which should be valued for its own sake.

On the other hand, "… without compromising the ability of future generations to meet their own needs" (World Commission on the Environment and Development 1987) is a phrase to which, perhaps, governments are sorry they have signed up: but sign up they did, when they proclaimed their allegiance to sustainability. There is an inconsistency here between policy pronouncements which major on sustainability, and recommendations for project evaluation which major on discounting.

6.6 Law

As for the law, we may look despairingly at our litigious societies, whose main focus appears to be legal support for present-day individuals in hot pursuit of self-interest. We may further reflect, that we cannot legislate against whatever legislative alleviations of intended obligations future generations may choose to make in their own interest. This also looks unpromising; and so it is, if we think of law as evolving not with *only the intention*, but also with *only the effect*, of promoting the well-being of present society or of vested interests within it.

In his play *Left-Handed Liberty*, Arden (1965) portrays that great charter of rights, the Magna Carta, as a devious tactic of revenge by King John against the English barons. For, in establishing freedom for themselves from the tyranny of the king, the barons also unintentionally established a principle of freedom for the common people from the tyranny of the barons.

In similar vein, there are few more famous words in history than: "We hold these truths to be self-evident, that all men are [was "will be" also intended?] created equal, that they are endowed by their Creator with certain unalienable Rights, that among these are Life, Liberty and the pursuit of Happiness". [And, by implication, the means—the resources—by which happiness may be pursued]. The Declaration of Independence supported freedom from slavery in an unambiguous way not entirely consonant with the ambivalent views on race and slavery held and implemented by Jefferson, a plantation owner himself. And, equally, it could pre-emptively support future generations against the tyranny of their ancestors.

Likewise, the *Code Napoleon* forbids legal exemptions based on birth and privilege. What could be a greater birth privilege over others, than to have the power to determine both whether they come into being and what, if any, provision should be made for their fulfilling existence? Its perspective finds a parallel in the "veil of ignorance" (Rawls 1971), under which ethical legislators in the original position do not know to what human condition they themselves will be born.

Inconsistency is hard to defend intellectually, where no morally relevant difference exists between the outcome of litigation between contemporaries, and the intergenerational judgements which are thereby implied.

The law may also accidentally favour future generations in another way. Suppose that a majority of stakeholders benefits from non-consumptive values of forests. Then, democratically based law will uphold their interest in the maintenance of a normal forest age structure, against the interest of a single owner concerned only about timber values. The latter's short-term interest lies in liquidating material values as soon as financial maturity—according to conventional criteria—has been achieved; and possibly in not regenerating the forest. But the law forbids it. Unintentionally, the interest in non-consumptive values by the majority supports the sustainability of timber production.

6.7 Communities of Interest

Turning to implicit social contracts, intertemporal issues have similarities with common property resource problems. To these, the institutional solution has been widely seen to lie through agreement of rules in use, social conventions and so on (Ostrom 1990; Bromley et al. 1992; Gombya-Ssembajjwe 1996).

But there is an institutional distinction from the usual grazing or fisheries exemplars. Irreversibly destructible ecosystems and non-renewable mineral resources are for sharing with future generations as well as with each other. So also do we share the limited capacity of the planet to absorb atmospheric CO_2. And so also do we share the limited capacity of the planet to offer appeasement of consciences over our self-indulgent lifestyle, by our paying for a few trees to be planted whenever we fly. Because of the globally limited capacity of forests to store carbon, buying carbon offsets today reduces the future's options of buying offsets.

The institutions that have been effective in governance of commons for the use of a defined, stable and contemporary set of beneficiaries are less plausible as regulators of open access resources for transient, mutually disengaged communities of different generations. For example, in the real and reflective world (outside the world of political triumphalism, that is) there was little confidence that the Kyoto process of negotiation would achieve a just result, even among contemporary stakeholders, all of whom had at least the possibility to be represented. How much less so, when the future recipients of this generation's decisions have no seat at any negotiating table!

In the same manner, Hobbes (1651) saw the enactment of "convenient articles of peace" as arising from negotiation towards mutual advantage, between contemporary parties who potentially wielded unpleasant powers over each other. But future generations have no such powers, except to curse our memory. And not many of my own generation appear to have been very frightened by that prospect.

It has been argued that the interests of future generations actually *are* represented in the trade-offs made, through private expressions of benevolent sentiments under which the present generation cares about the future generations whom it knows personally, and for whose betterment it makes provision (Rae 1834). But, even if this internalisation of values were to treat such others at parity with self, it is readily shown that the rational provision will be insufficient (Price 2006). Provision for the future based on *sentiments* will probably be limited, because of the felt *otherness* of those descendants who will be born beyond our own lifetimes. At most, the three or four following generations will be cared about. Beyond that, no provision would be made on affective grounds. Then, irrespective of whether individuals have naive or sophisticated expectations about how future generations will roll their inheritance forward to further generations, the weight given to *every* succeeding generation will be less than that given to oneself, and the provision made for later generations will accordingly be less generous.

Benevolent motivations will bequeath *some* fraction of wealth, but the worldly nature of a consumerist society exerts pressures that commute even this fraction, as life expectancies—but not work expectancies—increase, and as the elderly become more independent and more insistent on extending a self-indulgent life-style. Wheedling, nauseating voices of television equity-release advertisements tell us that we can remortgage our houses in arrangements that maintain the style of living to which we have become accustomed. They seek to persuade us that "… we can leave something to the grandchildren too": but fail to mention that we could have left a great deal more, had we been less self-indulgent.

To shift our motivations into a more embracing, self-effacing mode, we need to broaden the community of interest and fortify its claims on us.

> Rousseau (1762) considered that our obligations to others stem from membership of an abstract community. Golding (1972) attempted to extend this idea into the future, by postulating a "moral community" with which the present generation shares values (Price 1993, p. 190).

Against this, Barry (1977) regarded a requirement for shared values as "distasteful"; Goodin (1985) considered it "odious": it implicitly postulates a threshold of *sufficient similarity*, beyond which *otherness* disobliges us of caring.

Goodin's view is that we should act well towards future generations, not because of our common values, but because they are vulnerable to our hostility or indifference. The contractarian position is inverted: it is our power over future generations, not their power over us, that implants obligations. At this point, there is a decisive break with any self-interested motivation, except whatever derives from knowing that we are acting as we ought.

There are echoes here of an older morality, in the Biblical parable of the Good Samaritan—the person outside the accepted society who nonetheless delivers succour to someone in trouble. The very point of that story is the "otherness" of the Samaritan. Reversing the punch-lines of the parable: *to whom* was the Samaritan a neighbour? answer, faultless as a generalisation, the one to whom he showed mercy.

6.8 Pragmatic Ethical Imperatives

The declining discount rate protocol discussed earlier seems to promote a softly–softly approach to a greater emphasis on sustainability, without immediately abandoning our present instincts for discounting, nor the present comforts that derive from such a focus on ourselves. Its implication is, that the middle-distant future should sacrifice more for the far-distant future than the present does for the middle-distant future. There are, it should be said, foundations for hyperbolic discounting other than human psychological propensities. In general, they result from aggregating the results of multiple time paths of value (Price and Nair 1985; Price 1997, 2004, 2005), and are properly treated by *dis*aggregation. The psychological propensities that remain are due to inconsistency arising from the doer's perspective.

Also, in making provision for compensation or endowment to far-future generations—in arguing that compound interest at the mean expected rate of return is the desired and realistic transformation path of values through time—we implicitly assume that nearer-future generations will fully maintain that provision, until the due date for its realisation. We implicitly wish to commit them to this duty. The message is clear: we do *understand* that the very long-term is important: yet we do not feel *moved* to give the same weight to the near-future's well-being as we give to our own.

From the desire to give nearly equal weight to middle- and far-distant generations (in the manner of the planner), we could recognise the consistency of doing the same between ourselves and the next generation (overriding the judgement of the doer). Alternatively, such even-handedness of judgement could arise more directly, from a cognitive view that repudiates giving less weight to *any* future generation, merely on grounds of its futurity.

Suppose, therefore, that we accept that we should ideally accord and implement an equal weight to the well-being of others, despite their otherness. Suppose that we treat directly, and not by discounting for time's passing, whatever good reasons there might be for surmising that goods, services, and environmental conditions may create well-being in different measure—greater as well as lesser—in future. Then, there would be an immediate and radical shift in many resource allocation decisions. On this basis we would protect resources and environment more vigorously than we now do. There would be less depletion of the material and genetic resources of forests. We would generate fewer persistent pollutants, of which CO_2 is but one example. And, if we act in any way that damages future interests, we would ensure that a compensation fund is both created, and protected against intermediate depredations.

There can, of course, be no guarantee that future generations would follow this lead, maintaining real resources and continuing our compensating investments into the further future: they could treat us as suckers, and squander what we had provided for the benefit of later others. Whatever the moral integrity of those who endow compensation funds, they cannot guarantee that intervening generations will also act with complete propriety in leaving the fund intact. But if we, having debated the matter, determine that no concession is ethically required of us, nothing is more likely, than that future generations will follow that particular lead. Why should they act differently? If we are not moved by conscience, why would near-future generations be? In the hyperbolic context, why should we expect near-future generations to respect our relative judgement of their well-being and that of far-future generations, when our evaluation of our own well-being in relation to the near-future generation's is done on a very different basis?

There is the further effect that, no matter what succeeding generations do in the aftermath of our decisions, a residue of our own intention will remain. For example, if we deplete high-grade resources more slowly, there will always be a little more high-grade resource available to the future (Price 1984), be those minerals in the ground or tree stems above it.

An ethical problem remains, in the just allocation of burdens among generations. For example:

> … an investment may be financially costly in the short-term, environmentally costly in the long-term, and beneficial only in the medium term. Then, present investors may argue that it is unjust to expect them to pay compensation, when the investment is already a net cost to them: on the other hand the recipients of medium-term benefit might argue that it is unjust to require them to pay compensation to the long-term losers, when they played no part in the original decision (Price 2006).

It is also possible that middle- as well as far-distant generations have to bear environmental degradation, unless these costs are fully compensated by the present investors—who might, nonetheless, exempt themselves by arguing that they, the financial benefactors of all future generations, are thus made the scapegoats for all associated damage.

But these are rather fastidious objections, compared with the objection to the present generation's dismissive treatment of all future generations' ethically valid entitlements.

The objection can, and often is, made, that it is unjust to expect sacrifices from the poorest of all remaining generations: that is—under a belief of inexorable growth of affluence—ourselves.

There is, however, a rising counter-belief, perhaps for the first time in history, that we are the generation that has had it both ways, enjoyed the fruits of past exploitation, without suffering much consequence of resources depleted, climates deranged, or consciences disturbed: we, that is, who are the affluent citizens of the western world. Many of my generation, nearing the ends of their roads, are beginning to acknowledge this in private communication. In terms of Rawls's (1971) argument, we are the most unlikely to be "the least advantaged" of the generations that remain. Contrary to the position of Tullock (1964) and Schelling (1999), we may lie at the cusp between diminishing and increasing marginal utility; and so, among all generations, would make the least sacrifice of utility by curbing consumption. And, because of our habits of extravagant consumption, we are the generation to which all future generations are vulnerable, as never to a generation before us.

Such uncertainty about the future is not-to-be resolved in the traditional way, by increasing the discount rate and thus condemning the future's interests to even deeper oblivion. Instead, a precautionary principle should intercede for the interests of future generations. And, for us, there would be an increased likelihood of knowing, in retrospect, that we had acted rightly.

6.9 Institutions to Support Conscience

The question then is how, practically, can ought-ness be conveyed into is-ness, and even into will-be-ness? What can be done to support actually doing what we know we ought to do? What could support the planner against the doer? conscience against raw self-interest? the full cognitive appreciation of future generations' equal rights against our limited benevolent sentiments towards them?

First, we must be realistic about self-interest: it does not *sui generis* produce the desired result, as Adam Smith (1776) supposed that it might in the concourse of contemporary individuals and nations. As long as we hope *that*, we shall disappoint ourselves and our descendants. An equal concern for future generations cannot flourish within a contemporary social fabric of self-interest. Nor are the incentives of benevolent sentiments (as through private bequests) and overlapping interests (as in public mitigation of climate change) sufficient to represent the interests of future generations in the own right to which they are entitled.

But politics would prefer win–win solutions—for the crises of climate change and resource depletion as for others. We are told by governments that there need be no sacrifices. Sustainability is a win–win policy: wind turbine manufacture brings new jobs (which mysteriously have no opportunity cost); new green industries continue the increase and spread of the affluent lifestyle, without trespassing on the future's affluence; forests for biofuel are forests for biodiversity. We are told by airlines that we can compensate for our travels by planting a little more of a potentially infinite forest (whose land-base will be cheerfully and costlessly vacated by its peasant cultivators).

And every time such messages are projected and accepted, it becomes a little harder to advance the alternative message, that perhaps self-sacrifice is needed.

6.9.1 Religious and Secular Motivations

In earlier times, formal religion provided the incentives to act rightly and self-sacrificially, and not only towards one's contemporaries: punishment enacted or benefice withheld by future generations were available means of censure. Future generations might, or might not, pray for the repose of predecessors' souls. People desired to become an ancestor worthy of veneration; or to face with equanimity an inversion of Rawls's original position, in a final judgement made by the representatives of all generations who had lived.

Secular society and less judgemental forms of religion may share the ethical conclusions of traditional religion regarding right action, but they lack its compelling suite of censures and incentives. And even the force of traditional judgement is compromised by discounting of perpetual reward for right-doing or perpetual censure for wrong-doing (Azzi and Ehrenberg 1975)—though less so under hyperbolic than under exponential discounting. Only quieting a disturbed secular conscience remains.

6.9.2 Communitarian Pressure

We tend to pay attention to those who act consistently; who practise what they preach; who apply to their own lives the standards they demand of others. We admire them. We want to be like them, and to be admired in our turn. And there are such admired persons of previous generations too, whom we also seek to emulate. Perhaps it is consistency that in the end is the chief weapon in the battle against self-interest: consistency, that is, which provides a criterion for external audit, allied to conscience as a support to internal audit.

Obversely, in former times those who flouted the conventions of sustainable land management—especially those who said one thing but did another—were subject to censure. In like manner, the British politician who cycled greenly to his parliamentary work (but had a servant bring his brief-case along in the car) was pilloried for it in the media. Yes, people do challenge me, for occasionally flying halfway round the world to congresses, at which I speak of the irresponsibility of flying halfway round the world to …. And I plan more circumspectly, because I know that they will challenge me again.

Disengaged from a particular issue, one can still, apparently costlessly, apply censure to those who are inconsistent and impatient—those who are inconsistent particularly, because they can be judged against the standards that they themselves set up. At the same time one knows that one may be censured for the identical faults. And again, inconsistency and hypocrisy are charges that can more readily be brought, if one has judged others very publicly. But *not-judging* does not make one immune from censure; and ironically, high short-term discounting means that the future ill-consequences of detected hypocrisy weigh less than the satisfaction gained presently by judging others.

A more general demonstration of the inconsistencies and absurdities that arise from treating future generations differently should help to disturb the supposed intellectual foundations of so doing. Price (2005) depicts a programme of forest investment which is socially worthwhile if done now; but, according to a schedule of declining discount rates, it is *more* worthwhile if postponed for a generation. Thus, eventually, all generations agree that it is worth doing, and all postpone it, so that it is not done at all.

6.9.3 Creative Exhortation

The art and music of any age, and more explicitly its literature, reflect its ethos and the past events and thoughts which brought that ethos about. But creative works are also an institution that forms our consciousness of issues, and points to values that we ought to have and judgements that we ought to make. Much of the poetry which regrets the decline of the natural and human environment under economic forces focuses on loss of social structures (Goldsmith 1770; Clare 1827) and aesthetic qualities (Hopkins 1879; Betjeman 1958). Trees often appear as emblems of durability. Unfortunately, the sustainability of the economic resource base is a less glamorous and romantic subject (though Goldsmith does claim that pre-enclosure agriculture maintained livelihoods for a greater number of people). Nicholson (1972) treats the demise of the fossil-fuel-based Furness iron industry only from the perspective of the loss of community purpose and cohesion that it provided. The industry had originally been based on the sustained management of the coppices of the Furness Fells.

Modern novels, often written from a perspective of self-fulfilment of the protagonist, rarely re-present the ancient truth, that well-being comes from enacting the well-being of others—and even of *other* others?

One cannot legislate for the leanings of creativity, but perhaps creators should consider their responsibilities. They might draw inspiration from the folk- and fairy-tales that persist in many a culture, emphasising the forest, the need to care for it, and the consequences of not doing so.

6.9.4 Academic Institutions

Future generations have acute need for preceding academic institutions with the following characteristics.

- They are financed other-than by present-orientated bodies.
- They have a commitment to seek and promulgate the truth as best it can be found.
- They allow, as a matter of consistency, the recognition that the otherness of future generations is irrelevant.
- They are not constrained to ape commerce's view of the future in order to derive resources for short-term survival.
- Their members can criticise inconsistency and hypocrisy, without fear of compromising their own immediate employment status.

These do not seem to be what present political thinking is delivering to the world.

6.9.5 Internalising Sustainability

But when all is said and done, institutions will only be efficacious if the well-being of the future is powerfully internalised in the well-being of the present. That is, the present generation needs the offer of good which accrues in its own lifetime, and preferably immediately, in order that it will act for the benefit of future generations.

Sustainability means simply, the capability to be maintained indefinitely: it is not logically a good in itself, but only as the products indefinitely maintained are *themselves* an independently-judged good. But sustainability has long been treated as a present good—part of the good of *being* good—and, in pursuit of this bizarre custom, has in fact become a good in itself. The present generation so regards it, just as its ancestors did.

The prayer of Ignatius Loyola, that we might "labour and not ask for any reward, save that of knowing that we do your service", represents the end-point of the kind of internalisation process by which the good of others—of *other and future* people—is represented within the good of ourselves. Secularism needs to find an equivalent, or a substitute.

But it is a particularly heavy service, to be the means of happiness to those not yet born—perhaps never to be born: it needs a strange kind of cognitive detachment and joyless caring, which is hard to feel and hard to command. For the economically fastidious, signing up to the outcome of a cost–benefit analysis—a dispassionate form of appraisal of costs and benefits to whomsoever accruing—offers a kind of reward: an internal and external accolade for acting consistently, and for accepting results even if they lie outside one's narrow self-interest. However, let it be understood that discounting in such a cost–benefit analysis needs to be dissociated from irrelevant market rates of return and pure–purely self-interested—time preference rates. It should recognise that not all values flowing from ecosystems and social systems are subject to the same kind of diminishing marginal utility that affects the products of technological and financial systems (Price 1993, Chaps. 16–18; Kant 2003). Nor do increasingly abundant goods and services adequately replace goods and services which are in constant or declining supply. Nor should discounting due to diminishing *marginal* utility be applied to the *totality* of a resource's value.

6.9.6 Pre-commitment

If all this could be put in place, we might think it a faltering step towards [re–]establishing sustainable forest management, for maximum long-term benefit, as a permanent condition. But what is begun idealistically remains under continual threat of default from self-interested motives, by ourselves and by successor generations.

Pre-commitment is about deploying the insights of the planner to prevent or obstruct such later revision by the doer (Elster 1984). Planting species with a long growth cycle but highly valued product is one way—though in the UK, in the 1960s, established plantations of such species were poisoned and replaced with faster-maturing ones.

More generally, to engage in forestry is itself a form of pre-commitment, by locking investment into a form that cannot yield revenue for years if not decades. When the time comes for felling, the cost of regeneration can be envisaged as a charge against that revenue: it has indeed been so presented (Markus 1967). This is not, in any conventional economic view, a rational position (Price 1986): whatever it is that *results* from regenerating a crop, it cannot be the revenue from trees previously felled. But the illusion that it is so, does sustain forests. Such sustention is then reinforced by stakeholders whose interest is in continuity of benefit. Once started, it has self-interest behind it, because of the public desire for the forest's *state* as well as its *products*.

That much is in the nature of forestry. But I am not sure how effective it would be, to design, for that very purpose, lock-in covenants that show future generations how little we trust them to act rightly. As our descendants, they will have the capacity to act rightly or wrongly, just as we have, and for the same reasons. The example of how we acted will be the strongest advocate for rolling our viewpoint forwards.

6.10 Conclusions

Our affective judgement on the balance between the future and ourselves will not give the future the importance to which it is entitled in its own right. It may deliver forest management which is sustainable at a lower level of benefit than is possible, or it may deliver no sustainability, no management, no forests. Only an emphasis on cognitive judgements, together with ethical and social support for the rule of conscience, offers the distant future some hope that forests—and natural resources generally—will have been managed sustainably and to greatest benefit by preceding generations. That is, with a proper and equal account taken of the future's ongoing interests.

The soft web of support for conscience, as outlined above, may seem a fragile and diffuse institutional guarantor of future generations' well-being. But the institutions with formal structures, large capitalisation and big budgets amount to nothing, unless they support such ways of thinking.

It might seem an act of desperation for an economist to propose, as the way forward, the promotion of conscience and of all *(all)* the institutions that could support it. It's an extraordinary thing to ask of a fragmented world which finds difficulty even in caring about its own contemporaries. But I believe that this is the only hope that future generations can have in us.

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Part II
Public Choice Theory and Forest Resource Economics

Chapter 7
Public Choice, Rent-Seeking and the Forest Economics-Policy Nexus

David N. Laband

Abstract Although Adam Smith's recognition of humans' propensity to 'truck, barter, and exchange' was made in the context of private markets, this same propensity also applies to political markets. With the increasing recognition of, and appreciation for, the fact that forests generate multiple values, some of which are public goods, comes a strong implication that our understanding of sustainable forest management generally and forest economics specifically will be enhanced by explicitly incorporating principles of decision-making in a collective market context—public choice analysis. The self-interested behavior of politicians (elected), bureaucrats (unelected), and voluntary associations of individuals (NGOs) combined with the agency problems inherent to representative government has strong implications for the decision-making environment of private timberland owners. Unlike individuals who plant traditional row crops that are harvested after one growing season, timber growers make decisions that span (perhaps several) dozens of years. As public-ness aspects of forests increase in value, collective decisions increasingly will influence forest management generally and private decision-making by landowners. But long-term decisions made even under conditions of scientific certainty necessarily are made in a context of political uncertainty. This political uncertainty must be integrated into models of sustainable forest management.

Keywords Agency problem · Collective markets · Multiple forest values · Policy outcomes · Private markets · Political markets · Public choice · Rent seeking · Sustainable forest management · Voting

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D. N. Laband (✉)
School of Economics, Georgia Institute of Technology, 221 Bobby Dodd Way, Ste. 208, Atlanta, GA 30332, USA
e-mail: david.laband@econ.gatech.edu

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7.1 Introduction

Although Adam Smith's recognition of humans' propensity to 'truck, barter, and exchange' was made in the context of private markets, this same propensity also applies to political markets. With the increasing recognition of, and appreciation for, the fact that forests generate multiple values, some of which are public goods, comes a strong implication that our understanding of sustainable forest management generally and forest economics specifically will be enhanced by explicitly incorporating principles of decision-making in a collective market context. The self-interested behavior of politicians (elected), bureaucrats (unelected), and voluntary associations of individuals (NGOs) combined with the agency problems inherent to representative government has strong implications for the decision-making environment of private timberland owners. Unlike individuals who plant traditional row crops that are harvested after one growing season, timber growers make decisions that span (perhaps several) dozens of years. As public-ness aspects of forests increase in value, collective decisions increasingly will influence forest management generally and private decision-making by landowners. But long-term decisions made even under conditions of scientific certainty necessarily are made in a context of political uncertainty. This political uncertainty must be integrated into models of sustainable forest management.

In the latter part of the twentieth century, what has aptly been referred to as the 'Public Choice revolution' swept through the academic disciplines of economics and political science. Briefly, the central tenet of Public Choice is that the individuals in whom public trust is placed[1] are motivated not by the desire to improve social welfare but, rather, by the desire to improve their own personal well-being. This simple observation has dramatic implications for the design, functioning, and performance of political and social institutions narrowly and country-level economic performance more broadly; a large body of scientific literature that focuses on these implications has developed in recent years.

For example, there is evidence suggesting that macroeconomic indicators such as inflation and unemployment move systematically with election cycles. The notion that incumbent politicians exert (at least some, perhaps indirect) control over macroeconomic conditions in order to boost their (re)election probabilities is referred to as the political business cycle (Drazen 2008). The efforts by individuals and interest groups to use government as a means of re-distributing wealth in their favor are socially damaging, as they reduce economic growth (Olson 1965; Laband and Sophocleus 1992; Rauch 1994). Elected representatives cartelize public sector production, restricting competition and raising the 'price' (in the form of campaign contributions) of their services (McCormick and Tollison 1978). Indeed, there is evidence that politicians in the U.S., at least, deliberately introduce legislation targeting specific industries for onerous regulations as a means of

[1] This would include unelected bureaucrats and public sector employees in addition to elected politicians.

inducing firms in the potentially affected industries to ‘voluntarily’ contribute money to incumbent politicians who are in a position to make sure the legislation dies in committee, after the obligatory public bashing of industry representatives in front of a congressional ‘investigative’ committee (McChesney 1987, 1997).

With respect to the interface between politics and forestry/natural resources, recent contributions include the demonstration by Laband (2001) that voting in the political commons generates over-supply of environmental regulations targeting private landowners, analyses showing that special interest group politics influenced both congressional voting on the Endangered Species Act amendments in the United States (Mehmood and Zhang 2001) and congressional support for restrictions on imports of Canadian softwood lumber (Zhang and Laband 2005), a study by Tanger et al. (2011) showing that congressional support for environmental legislation in the U.S. over the period 1970–2008 was influenced by macroeconomic conditions, and superb contributions by Lueck and Michael (2003) and Zhang (2004) demonstrating that private landowners in close proximity to Red-cockaded woodpeckers (RCW), listed under the Endangered Species Act, pre-emptively harvest timber to preclude development of suitable habitat for RCW.

It should be understood, of course, that the economic performance of countries is nothing more than an aggregate of the economic performance of a large number of individual sectors of the economies of those countries. Thus, the observation that public choice theory has implications for our understanding of macro-economic performance generally suggests that a more refined focus of our scientific lens to an application of public choice theory to particular sectors and sub-sectors of the economy, such as the forest sector, not only may be desirable but, indeed, essential to our understanding of the structure, functioning, and performance of those (sub)sectors. With this in mind, my objective is to introduce and apply several highly-relevant and important aspects of public choice theory to forest economics, forest policy and sustainable forest management: Specifically, I focus on three aspects: (1) the relationship between voting and policy outcomes; (2) rent-seeking behavior, and (3) public versus private interests in science and policy. For the most part, my discussion is couched in terms of forestry practices and policies in the United States, but similar policies and practices are evident all around the world.

7.2 The Relationship Between Voting and Policy Outcomes

Forestry is shaped predominantly by markets, for inputs (e.g., land, labor, seedlings, herbicides and fertilizers) as well as the demand for final products. These markets are characterized by prices that reflect the values that both buyers and sellers place on the inputs and outputs. In turn, the information conveyed by these prices guides the investment decisions made by hundreds of thousands of individuals—landowners, land managers, seedling growers, home builders, and so on. In this context, the ‘invisible hand’ of private markets harnesses the self-interest of individuals in such a way that the social well-being of consumers is promoted (Smith 1776).

But these markets are impacted significantly by politically-determined conditions. Timber supply is affected by a host of political decisions, such as the amount of timber harvesting permitted on publicly-owned lands and regulations that determine the availability and cost of inputs, such as herbicides. Statutory restrictions on harvesting and other timber-related activities, re-planting requirements, and taxes levied on the profits that accrue from harvesting wood on privately-owned land all are determined by legislation. Likewise, political decisions also influence the demand for timber, wood products, and fiber products, such as cellulosic bio-fuels and paperboard. However, these political decisions do not necessarily, or even often, serve/promote the public interest. Failure to do so need not imply anything insidious about the motives or behavior of politicians. Rather, it may reflect one of the defining (and therefore crucial) differences between private markets and public markets with respect to decision-making: the efficacy with which preferences and values are expressed.

In private markets, preferences and values are expressed clearly and with great precision in terms of the prices that individuals are willing to pay/accept for goods and services. The individual who values a piece of fruit more than the selling price purchases and consumes it; importantly, no individual who values that fruit less-than the selling price is compelled to purchase and consume it. Decisions made in this context necessarily promote both individual and social welfare because exchange is voluntary; no one participates *unless* their welfare is enhanced by the transaction.

In public markets, individual preferences and values are expressed not in terms of money but in terms of votes and production and consumption decisions are determined by a process that aggregates these votes. Frequently, the candidate/issue/proposal that gains a simple majority of the votes cast 'wins', but the simple majority outcome need not to be economically efficient. A brief example will serve to demonstrate the potential inefficiency of a simple majority decision rule.

Each individual in a 3-member society is asked to vote express a preference between 2 forest conservation projects—(CP-1), which focuses on protection of endangered species to the exclusion of humans, and (CP-2), devoted to recreational uses for humans. In Table 7.1, the values attached to each project by each individual are identified. All three individuals place a positive value on each of the projects. Individuals A and B each value CP-2 twice as highly as CP-1 and vote accordingly. However, individual C not only values CP-1 much more highly than CP-2, the value he places on CP-1 is many times the collective value placed on CP-2 by all other members of society. Yet because the mechanism for revealing

Table 7.1 Values and voting on two forest conservation projects—I

	CP-1	CP-2
Person A	\$20	\$40 (x)
Person B	\$2	\$4 (x)
Person C	\$4000 (x)	\$6
Social value	\$4022	\$50
Votes in favor	1	2

Table 7.2 Values and voting on two forest conservation projects—II

	CP-1	CP-2
Person A	$20	$40 (x)
Person B	$2	$4 (x)
Person C	$44 (x)	−$3000
Social value	$66	−$2956
Votes in favor	1	2

social preferences for public works projects elicits only a preference between the two projects, not the intensity of desire for each project, a simple majority decision rule generates a less-than-optimal public sector production decision. The sub-optimality easily can be seen by contemplating a side payment from C to B in the amount of $3 and from C to A in the amount of $21, conditional on them both voting in support of CP-1. If this deal is made, total social welfare increases from $50–$4022 and *all* parties are better off.[2] But, political side payments of this sort typically are discouraged. Of course, in a majority-rule context, C need only arrange a side payment of $3 to B to generate a vote in favor of CP-1.

It need not be the case that all members of society benefit from both projects. As indicated in Table 7.2, one or more individuals (in this case C) actually may be injured by one or both of the projects being voted on. As before, both A and B vote in support of the park, and C is adamantly opposed to the park because it will impose substantial harm on him. Simple majority rule implies that CP-2 will be enacted, even though the total social value of CP-2 is negative. Again, relatively low side payments from C to A and C to B not only would make all three members of society better off, they would generate a positive social outcome rather than a negative social outcome.

Only in the extreme case of decisions reached by unanimous consent, we are guaranteed that all individuals, and therefore society as a whole, are better off (Buchanan and Tullock 1962). The potential inefficiencies introduced by less-than-unanimity voting rules coupled with how poorly votes reflect intensity of preferences may be magnified considerably by representative government. Although the United States and a number of other countries routinely are referred to as 'Democracies,' in fact they are Representative Republics, in which a relatively small number of elected representatives actually vote directly on policy initiatives. With a simple majority decision rule, a relatively small minority of voters potentially can determine policy outcomes.

Consider a society that consists of 121 individuals, divided equally into 11 political jurisdictions, each of which is served by a representative who is elected by simple majority. Representatives are chosen from one of two parties: the 'Donkeys' and the 'Elephants'. The distribution of the votes, in total and by district, is revealed in Table 7.3.

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[2] Note that C would be willing to pay up to $3,994 to induce A and/or B to vote for the dam. The improvement in social welfare would be the same but the distribution of the gains to individuals would change.

Table 7.3 An example of representative government

Party	1	2	3	4	5	6	7	8	9	10	11	Total
D	5	5	5	5	5	5	11	11	11	11	11	85
E	6	6	6	6	6	6	0	0	0	0	0	36

In this stylized world, the popular vote favors the Donkeys 85–36, a better than 2–1 margin. Yet the representative assembly is controlled by the Elephants, 6–5. Going further, it should be clear that each of the 5 individuals who vote for the Donkey candidate in districts 1–6 might have very intense feelings about that candidate, whereas each of the 6 individuals who vote for the Elephant candidate may have only a slight preference in this regard over the Donkey candidate. That is, in terms of reflecting values that are an essential basis for individual and social welfare-enhancing collective decision-making, representative government may dramatically exacerbate the likelihood that public policy: (a) is driven by a relatively small percentage of the voters, and (b) improves the well-being of select individuals while harming others.

7.3 Rent-Seeking Behavior

Through spending programs and regulations, governments redistribute wealth from certain individuals in society to others. This wealth transfer aspect of government can be extremely damaging to society. While we may agree that certain wealth transfers are desirable and promote the social good, the more general problem is that virtually every member of society prefers to receive wealth transfers rather than be forced (through taxation or regulation) to give his/her wealth to others. This aspect of self-interest leads inevitably to efforts by individuals to use the apparatus of government to arrange wealth transfers in their favor. In turn, such efforts motivate reciprocal efforts by other individuals seeking to prevent their wealth from being appropriated by the State. These expenditures by individuals to influence state-arranged wealth transfers are known as 'rent-seeking' (Tullock 1967; Stigler 1971; Krueger 1974; Posner 1974; Peltzman 1976). The scope and extent of rent-seeking activities has been found to be quite sizable, even in the western democracies (Laband and Sophocleus 1992) and fundamentally distorts our understanding of Gross Domestic Product (Mixon et al. 1994).[3] The fact that resources that could be used to enhance real productivity instead are used to

[3] As of this date (14 February 2010) a number of individuals are announced candidates to be the next governor of the state of Alabama—the election will be held in November 2010. It already has been noted by observers commenting in the newspapers that these candidates will spend millions of dollars in the hope of landing a job that pays only $110,000 per year. Of course, the Governor is in a position to steer highly lucrative state contracts to his friends, family, and business associates or to special interests who reciprocate with payoffs to the Governor in the form of campaign contributions (which eventually can be converted to personal use), highly-paid

influence the distribution of wealth implies that the economic well-being of countries is tied directly to the level of rent-seeking activity (Olson 1965; Rauch 1994). This is why graft and corruption inhibit economic growth, but then so do political campaign contributions.

The process of rent-seeking is well-understood. Successful rent-seekers will structure wealth transfers in such a manner that: (a) a relatively large number of people pay (the aggregate amount to be gained by the rent-seeking group is large), (b) each targeted individual pays only a small amount (so there is relatively little individual incentive to protest the wealth transfer), (c) the wealth is transferred to a relatively small number of recipients, such as industrial timberland owners, and (d) the motive for the wealth transfer is not transparent. That is, it does not pay to tell other people your actions are motivated merely by the desire to take their wealth from them. They will not feel good about this and fight to prevent the transfer from taking place. Therefore, wealth transfers invariably are disguised beneath a cloak of public-interest rhetoric, such as 'to help the children' or 'to save the environment'. People seem to feel better about handing over their money when it is for a noble cause. Wars against what are claimed to be particularly vicious enemies are an especially good cover for interest groups seeking wealth transfers. This explains why, for example, those who are skeptical about anthropogenic global warming are painted in such a negative light.

Arguably, almost everything related to the public policy process is driven, to some degree, by this wealth redistribution imperative. A not-so-subtle implication of this focus is that judging policy outcomes on the basis of social welfare maximization criteria is likely to prove frustrating, if not embarrassing. For example, I have argued for many years that not only could I actually win America's so-called "War on Drugs", I could do so quite cheaply and quickly. All that would be required is for the U.S. Government to lace several captured drug shipments with cyanide and put them back onto the streets. That is, mercilessly and definitively drive home the message that drugs kill. This simple and low-cost action would turn drug use from an activity with an expected positive return to users to an activity with an expected large negative return to users. I rather imagine that demand for cocaine and other illegal drugs in the U.S. would decline quickly and dramatically.

If we can agree that this strategy would, indeed, have the claimed effect—an immediate and very strong decline in demand by users—then we would agree that, in fact, America's War on Drugs can be won. This is a 'war' that we have been fighting for many decades now, that we have spent literally hundreds of billions of dollars on, that has cost many thousands of completely innocent individuals their lives, with extensive collateral damage outside of the U.S., and that by many accounts is a complete and utter failure in terms of reduced drug use/demand/availability. So why keep on pursuing the same policy failure for decades?

(Footnote 3 continued)
jobs for family members or friends of the governor, etc. The same general tendency pervades politics at all levels in the United States.

The answer is that the policy objective is not to actually win this war—the objective is to redistribute a lot of money. The War on Drugs is a multi-faceted means of funneling money (indirectly in the form of jobs) to many tens of thousands of judges, law enforcement personnel, social services workers, etc. The financial welfare of a large number of individuals depends specifically on continuation of the high-cost ineffective policy. That is, judged from a wealth redistribution perspective, America's War on Drugs has been a tremendous success rather than an abysmal failure.[4]

Note that it would actually be socially beneficial to win the War on Drugs and simply give the no-longer-needed judges, policemen and social services workers continuing payments for not working. But, of course, if voters really understood that the wealth transfer was the true objective, they never would agree to such a policy in the first place.

Members of the forestry community are, of course, no less immune from the seductive siren of rent-seeking than other groups. In casual conversation, private timberland owners in the United States are among the most conservative, anti-government individuals you will find. Yet many of these same individuals have lobbied state legislatures (directly or indirectly) to receive favorable tax treatment in several dimensions. For example, they favor protective government tariffs that reduce the competitiveness of softwood lumber grown in Canada (Zhang 2007). Several years ago my colleague, Daowei Zhang, and I created a bit of a furor in the forestry community of the southeastern U.S. when we rather bluntly pointed out this inconsistency (Laband and Zhang 2001).

Rent-seeking poses special problems for the forestry community generally and for timberland owners in particular. For example, in a number of countries, government officials control access to highly valuable timber resources on public lands. Timber is a resource that takes many years to mature. Consequently, timber management that is economically and ecologically sustainable implies a decision-making time-frame that is incompatible with the time frame of most government officials. They can personally appropriate the value from public assets only if the timber resource is exploited while they are in office. So they are particularly susceptible to rent-seeking efforts by companies that are willing to get in and harvest timber immediately.

This is why 'illegal' logging is such a difficult problem to deal with. When faced with charges of illegal logging taking place in their country, self-interested government officials either deny that a problem exists or refuse to take action because they likely have a financial stake in that illegal logging. To say that they are wrong is to deny the importance of human nature. The problem is not political corruption *per se*, it is the fact that the incentives of the stewards of the land are not compatible with the incentives of the (current and future) owners of the land. This

[4] The interest groups with a financial stake in the failed War on Drugs have been joined, politically, by those who believe that using the targeted drugs is morally wrong. For more discussion of such political alliances between 'bootleggers and Baptists' see Yandle (1983, 1998).

incentive incompatibility problem implies that timber and other exploitable, publicly-owned resources will continue to be over-exploited unless they are given exceptionally strong legal protections.

In recent decades, human populations have become increasingly urbanized everywhere around the world. Not surprisingly, urban dwellers are not connected to the land the way rural dwellers are; their values and perspectives differ significantly. However, in countries with democratic governments urban dwellers share one important characteristic in common with rural dwellers: their votes count equally. As populations become more urbanized, then, urban dwellers increasingly are able to define and control policy outcomes that affect rural life. This might, perhaps usefully, be referred to as the political urban-rural interface and manifests itself in a variety of different dimensions. I'll focus on one aspect in particular: what I have referred to previously as the "Tragedy of the Political Commons" (Laband 2001; Hussain and Laband 2005).

As I noted in that 2001 paper (p. 22), "A serious threat to private landowners develops when citizens living in urban areas demand that private owners of timberland (definitionally located in rural areas) produce environmental amenities such as aesthetically pleasing views, biodiversity, animal habitat, and the like, provided the urbanites don't have to pay for it". This threat is actualized when urban dwellers: "…enforce their demands by using the political process to pass regulations that require landowners disproportionately to bear the cost of producing these environmental amenities".

Examples of such public policies abound. In certain locations around the world, private property owners are required to permit others access to their land in order to pick berries or mushrooms. That is, the non-owners have certain statutory rights of consumption. In the state of Oregon, private timberland owners are required by state law to replant within two years areas from which they cut trees. Other regulations specify permissible harvesting regimes (for example, the size and spatial patterning of clear-cutting timber, even on flat ground). In the United States, federal regulations pertaining to endangered species are incredibly restrictive and intrusive with respect to an individual's property rights.

These public policies are striking in one key respect: in effect they redistribute wealth from rural land owners to people who live in cities. That is, urban dwellers in the U.S. have the political power to control voting outcomes and pursue environmental amenities through policies that impose virtually all of the associated costs on relatively small numbers of private landowners. This generates what might be termed a "tragedy of the political commons".

Hardin (1968, p. 1244) introduced us to the tragedy of the commons. Hardin developed a stylized example of a communal pasture open to all comers. There are no private property rights to the pasture, or rules, customs, or norms for shared use. In this setting, each shepherd, seeking to maximize the value of his holdings, keeps adding sheep to his flock as long as doing so adds an increment of gain. Further, the shepherds graze their sheep on the commons as long as the pasture provides any sustenance. Ignorant of the effects of their individual actions on the others, the shepherds collectively (and innocently) destroy the pasture. As Hardin concludes (p. 1244): “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 freedom of the commons”.

Man’s exploitation of the political commons is analogous to his exploitation of natural-resource commons. Our majority-rule voting process, which permits a majority of citizens to impose differential costs on the minority, encourages overprotection of endangered species, and overproduction of biodiversity, animal habitat, and landscape views. It is precisely the wealth transfer aspect of the simple majority decision rule that generates an over-production of damaging policy.

Legal rule-making can be crafted in a manner that concentrates the costs of policy (there always are costs) on relatively small groups of citizens. This implies that, aside from this small group, other members of the society bear no (or essentially trivial) costs associated with the policy. In turn, this artificially skews individuals’ benefit-cost calculus in favor of over-production of environmental amenities because each individual who bears a negligible portion of the costs of providing environmental amenities has a private incentive to keep demanding additional environmental protections as long as there is any perceived marginal benefit. As with the overgrazed pasture in Garrett Hardin’s famous example, the result of overprotecting Bambi is, as has become apparent all over the eastern United States, both ecologically and economically disastrous. That is, we are creating social and ecological tragedies that result from the political commons.

The tragedy is compounded by the incentives generated for private landowners by these implicit wealth transfers engineered through democratic voting processes. When government intrudes on or appropriates the property rights of private landowners without compensation, the landowners have strong incentives to mitigate their expected losses. They can do so by changing their land use from timber production to housing or commercial development. There is little externally-produced (positive) incentive for landowners to promote habitat for endangered species; rather, doing so means only that use of one’s land will be seriously compromised by the highly restrictive provisions of America’s Endangered Species Act. Consequently, a landowner who finds a member of an endangered species on his property has a well-understood incentive to “shoot, shovel, and shut up”—our colloquial term for making sure that no members of an endangered species are found on his property. Such behaviors are not likely to help society achieve even widely-shared environmental objectives.

7.3.1 Linking Wealth Transfers to Excessive Environmental Regulations

It is worth pursuing further the argument made previously that because private owners of rural land bear the cost of producing biodiversity (and other environmental amenities), urban dwellers demand excessive amounts of it. The first point to be made in this regard is that urbanites do not in fact place a high value on biodiversity. One needs look no further than the readily observable behavior of urbanites for proof of this claim. Urbanites have the ability and prerogative to produce biodiversity on their own residential property. That is, they could let their residential lots grow wild with natural flora and fauna. This would, without question, promote ecological diversity. In practice, virtually no residential property owners, living anywhere in the United States or other industrialized countries, do this. Instead, they invest (implicitly through their time and explicitly by purchase) hundreds, if not thousands, of dollars annually in the care and maintenance of their lawns and grounds in a decidedly unnatural state. Like owners of intensively managed timberland, owners of residential property chemically treat and harvest the growth on their property. In so doing, they create a landscape with relatively little floral or faunal diversity. What this behavior reveals, of course, is that urban dwellers place a higher value on having their own aesthetically pleasing ecological deserts than on personally promoting local biodiversity, even when the latter would save them hundreds, perhaps thousands, of dollars each year. The clear implication is that urbanites simply do not attach much importance to biodiversity.

This leads directly to a second point: notwithstanding the observation that biodiversity is of little importance to them personally, urbanites may favor local, state, and federal statutes that ostensibly enhance biodiversity, provided such statutes impose the cost burden on others (e.g., rural landowners). The marginal, feel good benefit of such regulations may be miniscule, but with no personal costs to worry about, urbanites can be convinced to vote for them. However, if there were even a moderate cost to urban dwellers, we can be reasonably certain that restrictive regulations would not be passed. This explains why, for example, timber replanting regulations typically are not imposed on owners of residential properties who cut down trees.

As the divergence in values, perspectives, and knowledge about natural systems widens between urban and rural dwellers, the Tragedy of the Political Commons intensifies, as urban dwellers increasingly use their collective political might to transfer wealth from rural land owners, principally through land use restrictions and regulations. This clearly is a long-run issue in sustainable forest management.

7.3.2 Politically-Derived Risk and the Forestry Community

In contrast to traditional agricultural commodities which mature fully within the context of a single year (or growing season), timber is a crop that takes many years to mature. Consequently, it is very risky for timberland owners to assume that today's political environment (with policies that artificially influence markets) will remain in place over the length of time covering an entire rotation. The political forces that converged to deliver today's special price support, tax incentive, or artificially-inflated prices (e.g., pulpwood for biofuel; carbon credits) may not, indeed likely will not, be in place 30, 50, 80 years from now. Thus, the governmentally-influenced component of timber prices, land prices, and other prices associated with the forest sector is subject to a type of volatility and risk that is quite different from the volatility and risk that characterizes truly market-driven prices.

The reason that policies conveying advantage to special interests typically do not endure is because they are not politically sustainable over long periods of time. The fact that government officials create artificially high timber prices this year automatically generates opposition from other interest groups, such as home builders, who will argue that the government policies creating artificially high timber prices should be repealed. Where there is a lot of money at stake, it surely is the case that the affected interest groups will spend a lot of money in efforts to influence the outcome. Under the intense pressure of a major economic downturn, as tax revenues from traditional sources dry up, the special tax treatment of timberland may be open to reconsideration.

In turn, this government-induced volatility tends to generate political fragmentation within the forest sector. For example, individual land owners in the U.S. who currently have a lot of mature timber on their properties likely will favor a government policy that restricts imports of timber from other countries. Such a restriction will drive up the current price of timber in the U.S. generating a short-term profit opportunity for landowners with mature timber. However, such a policy inevitably will harm home builders, who may, on the margin, be driven to embrace non-wood building materials. This will, of course, impose considerable harm on those land owners who hoped to sell their timber for good prices 20 or 30 years from now.

As a second example, we already have seen that markets for carbon credits, which exist specifically and solely because of government policies with respect to carbon, temporarily create financial windfalls for certain timberland owners. Those who acquired carbon credits then sold their timberland when the price of those credits was high to buyers who believed the value of those carbon credits would remain high likely had some portion of the expected stream of future carbon credit payments capitalized into the selling price of their land. These timberland sellers are financial winners. Of course, when it becomes clear that the price of carbon credits will not remain high and the carbon credit-related stream of revenues will not materialize as anticipated, the value of that land will fall back to what is justified in consideration of the realizable and sustainable flow of revenues. Buyers of timberland who paid prices that included the capitalized stream of carbon credit payments will be financial losers when the price of their land falls as the price of the credits falls.

What this means, of course, is that while there may be a perception within the forest community that carbon credits are a no-risk money-maker for timberland owners, the reality is different. No doubt, certain current owners of timberland have benefited and will benefit financially. But those gains may, and likely will prove to, be transitory. As political support for carbon restrictions ebbs, we will be left with a mosaic of timberland owners—some who did not participate in the carbon markets, some who gained financially, others who lost financially.

The problem with lusting after government favors is that what the government does today can be undone and more tomorrow. But, of course, once a group has been the beneficiary of government-arranged wealth transfers, or, indeed, even lobbied unsuccessfully for such transfers, it loses its political innocence. Then it is too late for members of that group to claim, with any legitimacy, that this type of governmentally-arranged theft is objectionable.

7.4 Public Versus Private Interests in Science/Policy

The pursuit of self-interest in private markets characterized by voluntary transactions between informed participants necessarily improves social welfare. I have argued that in the context of political markets, self-interest can be, and frequently is, used to redistribute existing wealth rather than creating new wealth. From piracy to large-scale tribal or national butchery, mankind's historical record provides ample evidence of the immense importance of efforts to redistribute wealth.

Individuals kill each other over card games, affairs with spouses, lawsuits, property boundaries, illegal drugs, stealing cattle, on so on. For centuries, Jews consistently have been targets for abuse and murder in order to obtain their wealth. Slavery is, at heart, wealth redistribution, as the slaver appropriates the stream of labor services provided by the slave. If the slaver did not covet the value of these services, the slave would merely be killed. History-defining wars—such as America's War of Independence against England, America's War Between the States, and World Wars I and II—were engaged primarily because of wealth redistribution considerations. Surely the historical social toll of efforts to influence the distribution of wealth runs into the hundreds of millions of lives damaged or lost. Many otherwise good men and women succumb to the overpowering desire to appropriate their neighbor's wealth, in the process committing the most heinous of acts against fellow humans.

Individuals and groups strategically exploit majority-rule democratic processes in efforts to employ the power of government to arrange wealth redistributions from others. In both the public choice literature and, increasingly, the popular press, these self-interest-maximizing individuals are referred to by the rather derisive term, 'rent-seekers'. Although scientists generally are regarded by the public as dispassionate, arms-length seekers (and tellers) of truth, this implicitly assumes that scientists turn a blind eye to their own self-interest. However, since scientists are no less human than non-scientists, there is no reason to believe that they are any more or less motivated to pursue their own self-interest than other individuals are.

Empirical evidence regarding the self-interest of scientists is easy to come by. My colleague in Auburn University's School of Forestry and Wildlife Sciences, David South, has made offers to bet literally dozens of scientists around the world with respect to the claims they make. Only two (2), including my fellow economist and human population optimist, Julian Simon, have ever been willing to bet their own money on their science. Yet in their pursuit of (mostly publicly-funded) grants, these so-called scientists only too-obviously are willing to prostitute themselves in exchange for a few gold coins. In so doing, they not only destroy their own scientific virtue, they destroy the reputational capital of the scientific community and potentially damage the lives and well-being of literally millions of their fellow human beings. The lure of the wealth transfers is powerful indeed.

In my opinion, it is worth considering whether public policy with respect to anthropogenic global warming is analogous to America's continuing War on Drugs. A politically-strong collection of interested parties, including climate researchers, develops an enormous financial stake in manufacturing and sustaining a putative danger to the public well-being. This serves as justification to reallocate essentially incomprehensible sums of money from politically unorganized private citizens through taxation and regulation to combat the threat. Individuals engage in rent-seeking, including the continuing insistence of long-term danger, to capture some portion of these funds. To those who might be shocked, perhaps outraged, that I would dare to suggest less-than-noble motivations behind anthropogenic global warming science and policy, I refer you again to my colleague, David South. How many scientists making dire predictions about global warming are willing to bet their own money on the veracity of those claims? How many have relocated their homes from low-lying coastal areas to locations that, in theory, will not be adversely affected by their predicted rise in sea-levels? If they are not willing to do so, what does this imply about the confidence these scientists have in their own work/findings and, as a corollary, the confidence that others should have?

7.5 Conclusions

History reveals that economic models of the market process explain only part of what happens in the real world. Management decisions with respect to timber as well as ecosystem goods and services produced by nature generally, and forests specifically, are shaped by markets as well as politics. Consequently, real understanding of the forces shaping utilization of forest resources requires knowledge of how both private and public markets operate and interact.

A number of points are suggested by the foregoing discussion. First, depending on circumstances, political markets and commodity markets may be regarded as complements or as substitutes. Development of thriving private markets requires strong protections for private property rights. These protections are collectively defined and enforced. At this fundamental level, the functioning of the State and the functioning of private markets are strongly complementary. Moreover, because private markets do not effectively handle public goods aspects of forests, political decision-making may augment (complement) decisions made by private individuals operating in private markets. However, political markets may be used by self-interested entrepreneurs to separate consumers from their money; in this context rent-seeking is a substitute for profit-seeking activities in private markets. Second, political markets are based on voting, not prices, therefore results of political decision-making, even by direct democracy, are likely to be inefficient because votes do not accurately convey intensity of preference whereas prices do. Third, this inefficiency problem is exacerbated by representative government, because multiple-stage majority-rule decisions may result in a small minority of voters controlling legislative outcomes. In addition, political representatives are ‘bundles’ of numerous public goods/services; for specific elements of this bundle, the representative may not efficiently reflect a voter’s preferences. Fourth, the absence of private-market competition in public markets generates/exacerbates inefficiencies in the supply of public goods/services. Finally, sustainable forestry management requires allocation of both private and public goods; therefore it is necessary to understand the functioning of both types of markets and interactions between them. In particular, it is crucial to understand and appreciate how changing the relative mix between ownership and control of production affects management decisions and outcomes. In the classic agent-principal relationship in private markets, firms are owned by stockholders but managed by individuals whose objectives may differ substantially from those of the stockholders. Recognition of the public aspects of forestry forces us to acknowledge and deal with a related agency problem—forest lands may be owned by private individuals whose objectives, and therefore management decisions, may be controlled, or at least constrained/influenced by millions of voters who have different objectives for the land. This separation of ownership and control has important implications for sustainable forestry management.

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Chapter 8
The Political Economy in Forest Policy-Making: Economic Efficiency and Beyond

Daowei Zhang

Abstract The development of political economy and studies of political economy in forest policy -making are reviewed and a case study of U.S. policy-making in restricting Canadian softwood lumber imports is presented. The analysis presented demonstrates that interest group politics and political contributions have worked in the U.S. political and institutional settings and that the results are an inefficient forest products trade policy. The implications are that policy-making does not exist in isolation of political and social structure , and that the outcomes of theoretical economic models are greatly influenced by these structures. Forest economists and forest managers can better explain, anticipate, and predict the outcomes of various forest policy developments with a better understanding of political economy.

Keywords Economic efficiency · Forest policy · Interest group politics · Political contributions · Political economy · Political structures · Social structures · Softwood lumber trade · Trade restrictions · United States

8.1 Introduction

We forest economists have traditionally been concerned with the economic efficiency and distribution of income associated with the allocation of resources in forest production and conservation, forest products manufacturing, and forest

D. Zhang (✉)
Alumni and George W. Peake Jr. Professor, Forest Economics and Policy, School of Forestry and Wildlife Sciences, Auburn University, AL 36849 Aubum, US
e-mail: zhangd1@auburn.edu

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products marketing. Our works are concentrated in the areas of land use, multiple benefits, the valuation of non-market goods and services, optimal rotation age, silvicultural investment, landowner behavior, harvesting regulation and community stability, forest products trade, and forest-based industrialization. When dealing with forest policy, we often provide *analysis of policy* for public policy-makers and the public. Sometimes we use the results of our analysis to recommend and even advocate certain policy choices, and thereby provide certain elements of *analysis for policy*. With a few exceptions, we as group have not paid much attention to the details of the policy-making process ("politics") and institutional contexts ("polity"), and have thus largely ignored the political forces that affect the choice of policies.

Nonetheless, the forest economics literature has recently started to expand beyond the analysis of policy and into the political economy of forest policy and policy-making under various institutional settings. This expansion has enhanced our understanding of the political and institutional dimensions of forest policy and our collective professional contribution to society. In this chapter, I review the recent development of forest economics literature in the areas of political economy and explore some frontiers in forest economics research. I draw attention to the fact that forest economics and forest policy development do not exist in isolation of political and social structures, and the outcomes of theoretical economic and policy development models are greatly influenced by these structures. Forest economists and managers can better explain, anticipate, and react to various forest policy developments if they understand and appreciate the political and institutional structures under which forest policies are developed and political economy.

The next section provides a broad review of political economy, followed by a summary of recent studies in political economy of forest policies. Section 8.4 presents a case study on political maneuvers behind one of the most important forest policy issues in North America—the three decade-long U.S. restriction of Canadian softwood lumber imports—and highlights how interest groups use political campaign contributions to influence U.S. policy-makers. The final section concludes and identifies some areas for further research.

8.2 Political Economy

Political economy was developed in the 18th century as the study of the economics of the states, or polities. It was a term similar to economics we use today, covering the study of production, exchange, and consumption, and their relation with law, custom, and government, as well as the distribution of national income and wealth. Later, and perhaps because of the publication of Alfred Marshall's influential *Principles of Economics* in 1890, a shorter and more encompassing term, "economics" came to replace political economy.

Today, political economy may refer to many different things, including Marxian analysis of classes and class struggles and the public choice school of Buchanan, Tullock, and others that use economics to study politics, political process, and institutions. In this chapter, I use the term political economy more closely to that used by scholars in the public choice school, which is the study and use of economic theory and methods in politics and political process. Here I focus on policy-making, that is, how public policies are created and implemented and what the consequences are under certain institutional, social, and economic systems.[1]

Public policy-making may be explained by various theories. One of such theories is the public interest theory in which a democratically elected government serves as a representative and responsive agent and makes policy and decisions for the public. This is the ideal of "a government from the people and for the people". Thus, social planners in a representative government maximize the utility of a representative individual or the public as a whole. This public interest theory predicts efficient and effective government economic policies. Elected representatives, other politicians, and government agencies are assumed to be solely working for the interests of the general public and intending to maximize social welfare, public health, and social order. Thus, politicians and government agencies are benevolent guardians of public interest, hampered perhaps only by innocent ignorance as they search for the best policies.

However, experiences in various countries have often contradicted this theory. At the minimum, it is increasingly difficult to fit all of the complexities and varieties of experiences into this traditional representative agent model of government in economic policy-making. An alternative, the interest group theory, developed by economists in the public choice school, can better explain the continuing existence of bad economic policies.

The interest group theory starts with the assumption that policy-makers are self-interest agents and seeks to explore how political forces affect the choice of policy by paying special attention to distributional conflicts and political institutions, which are absent in the public interest theory. In particular, Buchanan, Tullock, along with Hayek, have made contributions in constitutional theory and in modeling politicians as self-interest agents. Stigler (1971) and Peltzman (1976, 1984) further develop the theory of economic regulations. Backer (1983) posits the model of lobbies, and Nordhaus (1989) contributes to the political business cycle model.

As politicians are modeled as self-interest agents, their individual and collective decisions are based on the availability of government-produced scarcity rents and their ability to maximize their benefits they may receive for producing these rents (Stigler 1971; Peltzman 1976; Becker 1983; Zusman 1976). Rents are broadly

[1] One may argue that political economy economy is the interplay between economics, law and politics, and thus can also analyze how institutions develop in different social and economic systems. I view that how institutions develop is the subject of institutional economics. In any event, I am more interested in analyzing and explaining the ways in which governments affect the allocation of scarce resources in society through their laws and policies and the ways in which the nature of the economic system and the behaviour of people acting on their economic interests affect the form of government and the kinds of laws and policies that get made.

defined and cover financial, political, or other personal gains. Because of self-interests, these politicians are subject to the influence of, and even captured by, special interest groups. In this case, special interest groups are the demander for, and the politicians are the supplier of, certain policies.

Stigler (1971) and Peltzman (1976, 1984) are among the first group of economists who posit full rationality and self-interest for all policy participants, including elected officials, bureaucrats, and private individuals and firms. They argue that all policy participants use the political process to seek wealth transfers and political and economic rents. In this model, policy analysis alone in the sense of Pareto efficiency would not be sufficient, since information on the size and distribution of economic impacts caused by a policy alone may explain the behavior of policy participants, but does not suggest how to change it.

Olson (1965, 1982) looks into the demand side for public policy and provides insights on how interest groups emerge, evolve, and function. He starts with the "logic of collective action", in which "free-rider" problems prevent the effective collusion of a large number of small losers or gainers. He then provides various hypotheses as to which pressure groups emerge and which groups are more effective. He points out that the characteristics of an industry that can organize itself and get its interests effectively represented include geographic, product, or market concentration.

Olson's model posits that economically inefficient outcomes arise because of free-rider problems. For example, it is rational for individuals not to join groups interested in consumer welfare, defined broadly, because the benefits to them are independent of their own activities. In other words, the cost of getting these individuals organized is prohibitively high, and consequently the demand for consumer welfare is diluted. On the other hand, industrial firms, even though they may be few in number, could be well organized if they are concentrated geographically, or in the products they make, or the inputs they need. When these firms focus on a single issue or issues that could bring them large benefits by imposing a small per capita cost on a large number of consumers, they as an interest group are more likely to successfully lobby elected officials and bureaucrats. Thus, issue-specific political participation is effectively precluded for large groups of small potential gainers or losers to represent their interests because high transaction costs prohibit them from becoming well organized.

This type of collective action problem has long been recognized by political economists. Pareto (1927) writes in reference to restriction measures in international trade, "A protectionist measure provides large benefits to a small number of people, and causes a very great number of consumers a slight loss. This circumstance makes it easier to put a protection measure in practice". Schattschneider (1935) puts it succinctly, "[b]enefits are concentrated while costs are dispersed". Many other economic policies are made because of this asymmetry in per-capita gain and loss between interest groups and the public.

As demanders for certain economic policies, interest groups often enter the political market by helping political candidates who share their views get elected and re-elected and continue to support them while they are in public offices. In this political market, the interaction between suppliers and demanders of economic policies are in the form of lobbying, pressure, political action, campaign contribution, legislation, and administrative actions.

Politicians, on the other hand, make policy decisions based on their self-interests and their assessments of the benefits and costs of responding to the demand from various interest groups (or lack thereof). These politicians can be viewed as agents or brokers because the real suppliers of policies are the individuals and groups that do not find it worthwhile to get politically organized and to effectively resist having their wealth taken away. Becker (1983) looks into the interplay of the competing political interest groups and politicians who rationally choose (that is, supply) policies in response to the competing interest group pressures to secure their rents. With competition among groups and the assumption that anything that benefits one group must either be financed directly through a tax or indirectly by charging higher prices to another group (including deadweight losses), Becker (1983) argues that resources are allocated through the political process to maximize the benefits (which are negative for the losing group) each group expects to receive.

Once in office, legislators and other politicians may engage in "logrolling". Such vote trading by legislators is usually done to gain sufficient support for a particular piece of legislation that benefits their electoral districts. Logrolling, which results in the redistribution of income toward certain regions and industries, generally does not lead to a more productive economy. Rather, it leads to unnecessary and costly public works projects and legislation that protects an inefficient domestic industry in certain districts.

This political logic is applicable to politicians in various political systems. In the U.S., it not only applies to individual members of Congress, but also to the presidents, even though U.S. presidents supposedly have a much broader constituency than individual members of Congress and would have less interest in favoring particular regions or industries. Firstly, these who help a presidential candidate get elected want and expect to get compensated in some forms from the president. Further, the U.S. Constitution based on the separation of powers doctrine limits presidential power. For example, Congress can greatly influence the president's trade policy, and U.S. trade remedies can be best understood by keeping clearly in mind the cooperation and tension between Congress and the executive branch over trade power. The president needs to act for the general good without offending certain congressional coalitions. On trade matters, this means that sometimes he must exercise his discretion for reasons not entirely related to the merits of a specific trade case. Often this give-and-take between the president and Congress in policy matters limits the options available for the president even if he wants to serve the public at large.

8.3 Studies of Political Economy in Forest Policy-Making

Forest policy is a study of forest participants, forest policy-making process, and actual forest policy programs. The latter, including, laws and regulations, taxation, subsidies, public ownership of forest resources, technical assistance, and landowner education, is sometimes labeled as forest policy. All policy programs made through a political process create winners and losers. In this section, I look at a few studies of forest policy-making in North America and elsewhere.

Some of the earlier leaders in the forestry profession in North America, notably Gifford Pinchot, were skilled politicians. Yet, even though some studies on various forest policies have noted the key players and their motivations, they are often chronological and descriptive in nature. Further, as noted earlier, most economic studies of forest policy are analysis of policy (looking into the impacts of the policy programs) rather than analysis for policy.

Other than policy spillovers from macroeconomic policies and other sectors such as globalization, collapse of the housing markets, and global financial crises, there are two significant policy developments in the forest sector in North America in the last three decades. One is the listing of the Northern Spotted Owl as a threatened species in 1989 (which affords it to the same level of protection as an endangered species under the Endangered Species Act) in the U.S. This development has resulted in some 80 % reduction in public timber sales in the U.S. Pacific Northwest, a major timber producing region in the country, and contributed to a high level of prices for timber as well as increased imports of forest products in much of the 1990s and 2000s. This policy development is often viewed as a battle between the environmental groups and forest industry. The environmental groups won the battle by cleverly using the U.S judicial system to force the U.S. Administration to comply with one of its environmental laws (the Endangered Species Act), much to the dismay of the forest industry. The involvement of forest economists in this case includes calculating the opportunity costs of preserving biodiversity (with the Spotted Owl as an indicator species) (e.g., Montgomery et al. 1994), evaluating various options (FEMAT 1993), and analyzing public timber harvesting policies on private forest management (e.g., Adams et al. 1996) and on timber-dependent communities (Burton and Berck 1996).

The other development is the U.S.-Canada softwood lumber trade dispute. Officially started in 1982 and still on going, it has been the longest and largest trade dispute between the two countries and largest trade dispute in forest products trade between any two countries. In the 1990s and 2000s, the dispute impacted some $5–7 billion softwood lumber exports from Canada to the U.S. per year. The involvement of forest economists in this case has expanded beyond the general market impacts of the trade remedies, which unequivocally show that free trade benefits the U.S. as a whole (e.g., Wear and Lee 1993; Zhang 2001, 2006), and into much of its political economy. In particular, Fox (1991) provides a chronology, and Anderson and Cains (1988) and Kalt (1988) focus on the politics and economics of the early rounds of the dispute. Zhang and Laband (2005) look into two key events when a majority of U.S. Senators wrote letters, demanding the U.S. Administration to impose restrictions on Canadian lumber imports. They find that the signatures (or lack thereof) on these letters from U.S. Senators are highly correlated with the relative importance of the forest industry and housing industry in their states as well as some aspects of logrolling. Zhang (2007) integrates the most relevant work from multiple disciplines and explains the political economy of all forest products trade (including lumber, shake and shingle, and newsprint) between the two countries. By looking into the causes, participants and their motivations, processes, legal and institutional frameworks, and outcomes as well as analyses at various stages, Zhang (2007) tells a multifaceted story and suggests possible solutions to the dispute. I shall turn to the most recent works on the political economy of this dispute in next section.

Coincidentally, I have developed a graduate-level forest policy course since 1995 that covers 4 Ps—the subject of policy (*property rights*, as I view all policy programs seeking to define or modify property rights), policy *participants*, policy *process*, and policy *programs*. Attentions have been paid to the theories and process of public policy formation as well as analysis of and for policy. A few students who took this course have since applied these theories to relevant forest policies and policy-making process. For example, Mehmood and Zhang (2001, 2002) study the Endangered Species Act amendments and the enactment of subsidies to state-level forest landowners and reveal that special interest group theory applies to both cases. Sun (2006a, b) looks into the federal Healthy Forests Restoration Act and state prescribed fire liability laws in the U.S. and draw similar conclusions.

A few other students have followed Zhang and Laband (2005) and started to look into to the production process of non-voting legislative events such as speeches, letters, resolutions, and co-sponsorship of bills. Since most congressional bills are not voted on and never become laws, their production process is much understudied. Tanger and Laband (2010) find that the co-sponsorship of the federal TREE (Timber Revitalization and Economic Enhancement) Act which benefits corporate forest landowners is highly related to the campaign contributions by forest corporations in the current legislative session. Zhang et al. (2011) take one step further and find a correlation between campaign contributions in previous legislative session and the co-sponsorship of the TREE Act. This confirms that interest groups make campaign contributions and help those share their perspectives to get elected. Further, Zhang et al. (2011) relate the timing of campaign contributions in the current session with co-sponsorship of the TREE Act. This is important because the interest groups (in our case, corporate forest landowners) cannot get all of their favored candidates elected, and they need other legislators to support their cases by strategically allocating campaign contributions to them right around the time when they are going to or have just signed on to the bills that these corporations want. By strategically allocating campaign contributions to these (core and other) legislators around the time these legislators make an action, the interest groups are able to exert more political influences than they otherwise would have with a limited budget.

Outside North America, there are a few studies on the political economy of global forest policies, mostly by political scientists and scholars in international relations (e.g., Cashore et al. 2004). Forest economists have looked into the causes of tropical deforestation, forest-based economic development, trade, and the role of forests in protecting global environmental goods such as climate mitigation and biodiversity.

Global forest policies focus on the allocation of global forest resources in economic development and environmental protection. Based on per capita income as an indicator of economic development and per capita forest cover as an indicator of

Fig. 8.1 The influence of per capita income and per capita forest cover on areas of priority concern in different countries (*Source* Maini 2003)

Netherlands Denmark Germany Japan UK "Forest Environment"	Canada Finland Norway Sweden USA "Sustainable development"
China India Kenya Somalia Philippines "Subsistence"	Brazil Gabon Indonesia Malaysia PNG "Economic Development"

forest endowments, Maini (2003) proposes the four clusters of nations regarding their primary concerns of global forest management and the possible reasons that drive these concerns. The forest-rich developing countries, such as Brazil and Indonesia, view forests as an important instrument for economic development. The forest-rich industrialized countries, such as Canada and Finland, often have the capacity and political support to pursue sustainable development. Forest-poor developing countries such as India, Kenya, and the Philippines, often use forest for subsistence. Finally, forest-poor developed countries such as Denmark, The Netherlands, and the United Kingdoms, rely on forest-rich countries to meet their high demand for forest products and services and often place a higher value on the environmental aspects of forests than developing counties. This simple clustering of countries (Fig. 8.1) may help explain why these countries have taken different positions in the international dialogue on forests and their attitudes on various international forest programs and proposals. Humphreys (1996) and Maini (2003) document these dialogue and international programs such as Tropical Forest Action Plan and the Intergovernmental Panel (Forum) on Forests (IPF/IFF).

In addition to government-to-government initiatives and dialogues, environmental groups proposed, in the early 1990s, a forest certification program that includes forest management certification, chain-of-custody certification, and ecolabeling. These groups, as participants of global forestry policies, were not satisfied with the slow pace in the government-to-government cooperation towards global forest conservation and sustainable development in the later 1980s. Subsequently they developed a Forest Stewardship Council forest certification program. This move challenges the traditional government rule-making authorities (Humphreys 1996) and has since forced forest industry and landowners in various countries to develop their own forest certification programs. Cashore et al. (2004) compare the politics of forest certification in five countries and reflect on why there are differences regionally, and assess the ability of private forest certification to address global forest deterioration.

The development of forest certification is based on the notion that, given a choice, consumers would prefer or pay more for eco-labeled forest products. If either were true, then forest industry firms would have a market-based incentive for independently verified, good forest management. Forest economists have initially looked at the willingness-to-pay and actual behaviour of consumers towards certified forest products (e.g., Smith 1999; Anderson and Hansen 2004; Anderson et al. 2005) and the cost of implementing various certification programs on private and public forest lands (e.g., Brown and Zhang 2005).

8.4 Money Matters: The U.S. Policy-Making in Restricting Canadian Softwood Lumber Imports

In this section I present a case study of U.S. policy-making process in the U.S.-Canada softwood lumber dispute. It is based on Zhang (2007) and a recent study by Godwin and Zhang (2012). The latter looks into all identifiable legislative actions in U.S. Senate in a 6-year period from 2001 to 2006 in the U.S.-Canada softwood lumber dispute. I note the political and institutional settings and highlight the role of political campaign contributions from interest groups in the U.S. policy-making of restricting Canadian softwood lumber imports.

The U.S.-Canada softwood lumber trade dispute started around 1980 when some U.S. producers saw that Canadian producers increased their share in U.S. markets. They alleged that Canadian lumber producers were subsidized by their federal and provincial governments, mostly through a low stumpage payment on public timber. Since then, there have been four rounds of trade dispute. Other than two short free trade periods between 1982 and 1986 and between 1994 and 1995, some forms of trade restrictions have existed for the last 30 years. The last restrictive trade agreement (the Softwood Lumber Agreement of 2006) does not expire until 2013 and has an option to extend another two years. U.S. producers were estimated to have gained US $3–5 billion (in 2000 constant dollars) each in economic rents as the result of the restriction measures between 1987 and 1991 (Wear and Lee 1993) and between 1996 and 2001 (Zhang 2001, 2006).

The major interest groups in the dispute are U.S. lumber producers (including timber producers), U.S. consumers (home builders and home buyers), and Canadian producers. U.S. producers want to restrict Canadian lumber thereby raising domestic lumber prices and their level of production and profits. U.S. consumers want affordable lumber for home building. Canadian producers prefer free trade and open access to the U.S. market. As Canadian producers cannot directly participate in the U.S. political market, they rely on U.S. consumer groups who have similar interests to influence the U.S. government. U.S. consumers, however, are at a disadvantage to U.S. producers, because under U.S. trade law they do not have a standing in the dispute and cannot participate in the negotiations and legal battles, even though they eventually pay most of the costs associated with any tariff or other restrictive measures on Canadian lumber imports. They do, as a competing interest group of the U.S. lumber industry, lobby U.S. Congress and Administration.

With a negative determination from the U.S. Department of Commerce in 1983, U.S. producers lost the first round of the fight. Shortly after that, U.S. producers re-organized and regrouped. They intensified their lobbying efforts to U.S.

lawmakers who then turned up the heat on the Administration and Canadians in 1985 and 1986. They eventually won the second round of the war by securing a Memorandum of Understanding in 1986 that applied an export-tax on Canadian lumber, even though President Reagan was pro-free trade and intended to have a comprehensive free trade agreement with Canada.

The very first sign that U.S. producers lobbying worked was when U.S. Senators in the Finance Committee refused to grant a "fast track" authority to President Ronald Reagan to negotiate the free trade agreement with Canada.[2] Under pressure, the Reagan Administration promised to "get timber fixed" (Zhang 2007). It was on this promise that President Reagan's request for the fast track authority was not denied by a 10–10 vote in the Finance Committee. Since then, the U.S. timber industry has continued to secure support from a group of U.S. senators and the Administration.

So when the Softwood Lumber Agreement of 1996 signed by the two countries were set to expire in March 2001, U.S. lawmakers began to write letters, make speeches, and introduce bills and resolutions to influence the course of actions in the negotiations and legal processes surrounding this dispute. These activities went on during the whole period of the 2001–2006 (4th) round of the softwood trade dispute. Because this round of the dispute was a continuation of the longer trade war, American lumber producers had already capitalized the economic rents of the trade restrictions into their businesses. This gives legislators some power in extracting rents, since businesses have grown to expect the additional income from the trade protection (McChesney 1987). This is another possible explanation why legislators try signaling their willingness to protect the lumber industry's economic rents.

In any event, all forms of legislative actions can be studied qualitatively and quantitatively by looking at the demand-side and supply-side factors of these actions. Godwin and Zhang (2012) look into 14 known pro-lumber restriction activities between 2001 and 2006. These activities varied, but fell into three broad categories: sponsorship or co-sponsorship of legislation, endorsement of letters sent to the Administration supporting the continued restriction of Canadian lumber, and hearings and statements made on the Senate floor. They find that the importance of the wood products manufacturing industry in a state, campaign contributions from both forest and housing industries, logrolling, and ideology played a significant role in senators deciding whether or not to signal their support through these activities.

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[2] The president needed the support of the Senate Finance Committee before the start of the free trade talks. Since Congress has jurisdiction over trade and commerce, the president cannot rely upon his inherent foreign relations power to negotiate an international trade agreement and ensure that it will be faithfully implemented by Congress. So when the free trade negotiation process started, President Reagan made it clear to Congress that he wanted a "fast track" negotiating authority, under which Congress would not be allowed to offer amendments before voting to ratify the resulting agreement. If the request for a fast-track authority was approved by the committees of jurisdiction (the House Ways and Means Committee, which did not act on this request, and the Senate Finance Committee), the president could proceed with negotiations and the resulting agreement would then be put to the Congress for approval, which requires a simple majority.

Table 8.1 Tobit regression results of factors influencing 14 pro-trade restriction activities in U.S. senate from 2001 to 2006

Variable	Coefficient
Importance of forest industry (% of forest industry's contribution to state gross product)	0.9946[c] (0.3310)
Total forest industry campaign contributions (in \$1,000)	0.0335[c] 0.0093)
Total housing industry campaign contributions (in \$1,000)	−0.0291[b] (0.0134)
Opposition to subsidies (1 for opposing trade barriers if a senator voted for subsidy bills at least 50 % of the time over his/her career, and 0 otherwise	−2.5413[c] (0.7771)
Opposition to tariffs (1 for opposing trade barriers if one voted against trade barriers at least 50 % of the time over his/her career, and 0 otherwise)	0.0324 (0.6525)
Finance committee membership (1 if a committee member, 0 otherwise)	0.8578 (0.6057)
Party (1 if Republican, 0 otherwise)	−0.0824 (0.6597)
Border (1 if a senator's state shares a border with Canada, 0 otherwise)	1.0250[a] (0.6183)
Constant	−0.6438 (0.6743)
Log likelihood	−166.4924
AIC	3.190
Mckelvey & Zavoina's R^2	0.478
No. of observations	111

[a, b, c] denote significance at the 10, 5, and 1 % levels, respectively. Numbers in parenthesis are standard deviation

Note The dependent variable is the number of pro-trade restriction events a senator participated in this period and ranges from 0 to 14. Since the dependent variable is truncated at 0, a Tobit regression is used

Source Godwin and Zhang (2012)

Table 8.1 presents their Tobit regression results. The dependent variable is the 14 events and is truncated at 0. The independent variables include the supply (such as a legislator's ideology and voting record) and demand (such as the importance of forest industry and campaign contributions from interest groups) sides for legislative actions. As expected, the amount of campaign contributions that a senator receives from the forest industry had a positive impact while the amount of campaign contributions from the home building industry had a negative impact. More interesting, however, is that the coefficients (0.0335 vs. −0.0291) are nearly identical in magnitude but in opposite signs. This indicates that the amount and the source of campaign contributions are related to the willingness of senators to exercise political pressure and the type of actions that they take. Thus, all else being equal, a \$30,000 contribution from the forest industry would likely to capture a senator by enticing him or her to participate in at least 1 pro-trade restriction event (30 * 0.0335 = 1) against Canadian lumber imports while an roughly equivalent amount of contribution from the housing industry would nullify

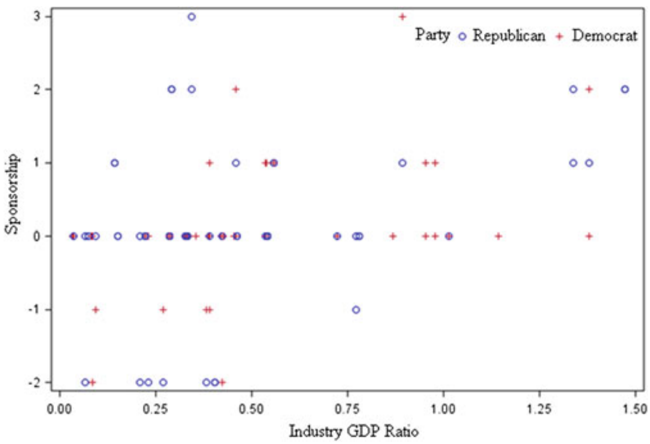

Fig. 8.2 The relative importance of forest industry and housing industry in a state and the co-sponsorship of pro-trade restriction bills (+ in Y-axis) and pro-free trade bills (− in Y-axis) from the U.S. senators related to canadian softwood lumber imports

this effect. Money apparently influenced the U.S. political decisions in the softwood lumber dispute.

The regression results also show that the importance of the forest industry, voting records (opposite to subsidies), and logrolling (as states bordering with Canada are more likely to produce similar products to Canadian provinces and thus senators from these states could support each other in various disputes with Canada) affect senators' actions. On the other hand, party affiliation, membership in the Finance Committee, and opposite to tariffs are not significant, although trade restrictions here mean actual subsidies.

Here I present five pieces of legislations—three pro-trade restriction, and two pro-free trade—and show graphically how money influences the senators' signatures on them. A senator receives a +1 for each piece of three pro-trade restriction legislations supported (Sen. Con. Res. 8: 2001; S.219: 2003; S.2992: 2004) and a −1 for each of two pro-free trade legislations (Sen. Con. Res 4: 2001; Sen. Con. Res 135: 2002). Figure 8.2 shows the relative importance of forest industry vs. housing industry in a state economy and its impact on a senator's signature on these legislations. The horizontal axis is simply an approximation of the ratio of forest industry's contribution to gross state product and housing industry's contribution to gross state product, which is positively related to the signature on the pro-trade restriction legislations (and negatively to the pro-free trade legislations). This positive relationship, however, is a bit fuzzy and casts some doubts about the relationship between the relative importance of forest industry vs. housing industry and legislative actions.

Note The Y-axis is a measure of how many times a U.S. Senator sponsored legislation concerning Canadian softwood lumber imports. A Senator receives a +1 for each piece of pro-softwood lumber trade restriction legislation sponsored (Sen.

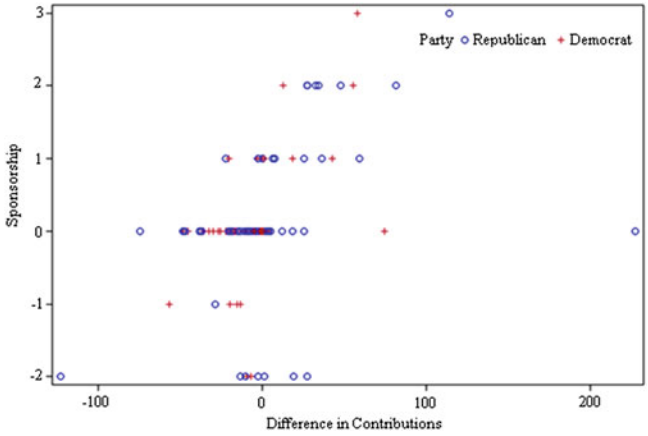

Fig. 8.3 Political campaign contributions received by U.S. senators and their co-sponsorship of pro-trade restriction bills (+ in Y-axis) and pro-free trade bills (− in Y-axis) related to canadian softwood lumber imports

Con. Res. 8: 2001; S.219: 2003; S.2992: 2004) and a −1 for each anti-softwood lumber trade restriction legislation sponsored (Sen. Con. Res 4: 2001; Sen. Con. Res 135: 2002). The X-axis is a ratio of the forest industry's (sum of wood manufacturing industry, the paper industry, and 50 % of the Forestry, Fisheries and related activities) contribution to gross state product for 2004 over the value of new housing as a percent of the gross state product for 2004.

When I replace the X-axis with difference in campaign contribution (Fig. 8.3 where contribution from forest industry is positive and that from the housing industry is negative) or ratio of campaign contribution [(contribution from forest industry-contribution from housing industry)/(contribution from housing industry + contribution from forest industry)] from the two U.S. industries (Fig. 8.4), this positive relationship becomes much clearer. The more the campaign contribution is from the forest industry in his or her state, the more likely a senator from that state would sign on one or more of the pro-trade restriction bills and resolutions. On the other hand, the more the campaign contribution is from the housing industry, the more likely a senator would sign on the pro-free trade bills. This relationship exists irrespective of the senators' party affiliation, which is an approximate for ideology. This result is supported by the Tobit regression results noted earlier.

Note The X-axis is the difference in the total contribution received from the forest industry and housing industry in $1,000. The contributions represent the total real amount for the 2000 through 2006 election cycles, using 2000 as the base year for inflation indexing purposes.

Interestingly, the numbers of senators that have not supported either pro- or anti-trade restriction legislative events are quite large, and most of these senators do receive some campaign contribution from either or both industries. There are at least three explanations to this phenomenon. First, interest groups may make

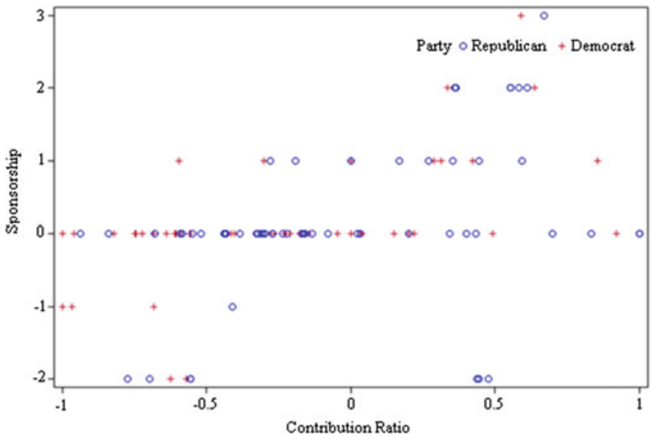

Fig. 8.4 Ratio of political campiagn contributions received by U.S. senators from forest industry and housing industry and their co-sponsorship of pro-trade restriction bills (+ in Y-axis) and pro-free trade bills (− in Y-axis) related to canadian softwood lumber imports

contributions to these senators for legislations other than softwood lumber trade. Second, interest groups may compete for political favour by making contribution to the same senators. These groups may want to hedge their bets and at least try to prevent these senators from going to the opposite side of their position. Finally, these senators may have played their cards well and have appealed both interest groups on this and other issues.

Nonetheless, it is clear that money indeed matters in this case, and it perhaps matters more than the relative importance of an industry vs. its competing industry. In fact, Figs. 8.2, 8.3, and 8.4 show that the relative importance of an industry (forestry vs. housing) in the state economy is not as a big factor in the decision making of senators as the political contributions from the industry. A small industry may gain more legislative supports than a bigger, competing industry if it raises enough political contributions and allocates them wisely to legislators.

Note The X-axis is a ratio of the difference in the total contribution received from the housing industry and forest industry over the total contribution received from the housing industry and forest industry. The contributions represent the total real amount for the 2000 through 2006 election cycles, using 2000 as the base year for inflation indexing purposes.

These results support the interest group theory. The amount and sources of campaign contributions received are indicative of where a U.S. Senator stands and what he/she will do in the dispute. The policy reference is that U.S. policy-making follows money, and thus free trade in softwood lumber or any other goods and services could be greatly enhanced when the money trail is broken or restrained. Despite the overwhelming theoretical and empirical supports that show free trade in softwood lumber and other goods is economically beneficial to the U.S. as a whole, trade restrictions still happened and will exist in some forms and fashion for a long time because institutional setting and political system in the U.S. only change slowly. More broadly, we will continue to see various forest or other public policies that are either designed for, or influenced by, special interest groups that can make more political contributions than the opposing interest groups.

8.5 Summary and Further Studies

Forest economists have started to look more at the political economy in forest policy-making. I have shown that the political process and institutional settings affect the outcomes of the long-lasting U.S.-Canada softwood lumber dispute. In this case, the demand for re-distribution of income has overwhelmed the considerations for economic efficiency, and political campaign contributions are more important than the size of the competing industries. The interest group of forest industry demands for such re-distribution and has skillfully utilized the political and institutional arrangements to its advantages. It has aligned itself with, and financially supported, a group of key senators, and has outcompeted the often larger housing industry to get what it wanted—the restriction of Canadian lumber imports.

Had we only looked at the economic efficiency aspect in this case, we would have been frustrated with an apparent paradox in this case—economic efficiency calling for free trade and the reality being persistent trade restriction. Further, by looking at the political process in the institutional setting, we find that money (political campaign contributions) is the "evil" and that the access of people with money to politicians needs to be curbed before things can get better.

The implications are that economic decision-making does not exist in isolation of political and social structures, and that the outcomes of theoretical economic models are greatly influenced by these structures. Thus, forest economists and forest managers can better explain, anticipate, and predict the outcomes of various forest policy developments with a better understanding and appreciation of the political and institutional structures under which forest policies are developed and political economy.

I call for more political economy studies in forest policy-making. These studies should go beyond economic efficiency and explore the political and institutional dimensions of forest policy in various countries and international arena. They can be done in traditional forest policy programs such as regulations, taxes, subsidies as well as emerging market-based instruments such as forest certification schemes, tradable emission permits, conservation easements, and various programs for endangered species protection. These studies can help understand why some policy programs work well and others do not in a jurisdiction and why similar programs have produced different results in different jurisdictions. They can also help the design, implementation and evaluation of various policies. For example, the cap-and-trade programs such as Acid Rain program implemented in the Great Lakes Regions of the U.S. and Canada and the NO_x Budget Trading Program in the US Northeast worked relatively well. So are the wetland mitigation banking and Safe Harbor Program in endangered species in the U.S. Yet the U.S. does not have a good program to reduce CO_2 emissions to combat climate change. Similarly, paying for ecosystem services has been implemented and works well in Costa Rica, but not other developing countries.

Further studies can also be applied to the responses of global forest sector to protect global commons, including climate mitigation, biodiversity conservation, the promotion of woody-based biomass production, and REDD+ (Reducing Emissions from Deforestation and Forest Degradation and the Role of Conservation, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks in Developing Countries) that is aimed at generating the requisite transfer flow of resources to significantly reduce global CO_2 emissions from deforestation and forest degradation. Exploring the political and institutional dimensions of these economic and policy issues will generate new insights into their design and performance and help expand coverage and contribution of the forest economics profession.

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Part III
Systems Approaches to Forest Resource Economics

Chapter 9
Economics of Forest Ecosystem Restoration: A Systems Approach

Runsheng Yin and Minjuan Zhao

Abstract Ecological restoration programs (ERP) and payments for ecosystem services (PES) have both attracted broad international academic and policy attention. While they are inherently linked and should be treated as integrated social-ecological systems (SES), they have been largely pursued by restoration ecologists and socioeconomic scientists separately, which is not conducive to the achievement of their common goal—sustainable ecosystem management. What this chapter does is to elucidate the potential limitations in the current ERP and PES research and call for truly integrated and more relevant studies to provide effective guidance to ecological restoration and ecosystem management. To that end, the authors will first review the primary research developments and bodies of literature in ERP and PES as well as in studying SES. Next, a systems framework that integrates social and ecological processes will be proposed, which will then be used to analyse China's recent experience in converting degraded cropland to illustrate the need for and possible ways of treating both ERP and PES as part of an integrated process of forest ecological restoration and ecosystem management.

Keywords China · Ecological restoration · Ecosystem management · Payment for ecosystem services · Sloping land conservation program · Socio-ecological systems

R. Yin (✉)
Department of Forestry, Michigan State University, 110 Natural Resources Building, East Lansing, MI 48824, USA
e-mail: yinr@msu.edu

R. Yin · M. Zhao
College of Economics and Management, Northwest Agricultural and Forestry University, No. 3, Weihui Road, Yangling 712100, People's Republic of China
e-mail: minjuan.zhao@nwsuaf.edu.cn

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9.1 Introduction

The international science and policy communities have come to the realization that restoring degraded ecosystems stands out as an imperative in order to improve the state of the earth (UNEP 2008; Palmer and Filoso 2009; Comin 2010). The Millennium Ecosystem Assessment (MA 2005) stated that “Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber, and fuel… The degradation of ecosystem services could grow significantly worse during the first half of this century….” Therefore, “It is not enough to conserve or protect, it is necessary to restore, and to do so on a global scale, since degradation also happens on a global scale (Comin 2010, p. xviii)”.

Likewise, in the context of contemporary forestry, management is no longer limited to forest protection and regeneration, as well as timber harvesting activities; restoration has become a critical component due to the widespread degradation of forest and other ecosystems on the one hand and the increasing pressures put upon these ecosystems for providing various services on the other (FAO 2010). However, restoring degraded ecosystems involves both natural and social components and processes in a more complex way, as compared to timber harvesting and forest protection and regeneration (Yin 2009). While this has opened up a major new dimension to forestry, it also pushes the profession into “uncharted territory,” in which it may not be completely prepared to take advantage of the emerging opportunities.

Historically, the primary attention of forest economics was devoted to timber production based on an approach of net present value maximization (Faustmann 1849; Samuelson 1976). While the analytic scope has been expanded into environmental amenity and other benefits (e.g., Hartman 1975), the basic approach has not changed. This combination of narrow focus and simplistic approach has been termed “Faustmann economics” (Kant 2011), due to not only Faustmann’s (1849) great contribution to the determination of optimal timber rotation but also the inertia of forest economics in moving beyond it. Of course, whenever timber is the predominant service that society derives from forests, the Faustmann economics remains relevant. Nonetheless, the fundamental societal landscape and policy issues that forest economists face in the 21st century are so different from Faustmann economics that it cannot be seen as adequate anymore.

For instance, while some of the forest ecosystem services are private goods, others are collective goods, and still others are public goods (MA 2005). And the relationships between these ecosystem services are complex—some are complementary, others are competitive; some can be provided under intensively managed plantations, others must come from undisturbed natural forests…. This multiplicity and complexity calls for a more comprehensive and capable analytic framework and approach. In comparison, timber is a private good and timber production is a simple process to analyze. Also, analyzing timber production can be done at the stand or forest level (Yin and Newman 1997), whereas it makes more sense to conduct ecological restoration assessment and ecosystem service evaluation at the landscape or even regional level. Additionally, it is almost impossible to separate the effects of different natural and social components on restoration and management outputs. Hence, there is a great need for a systems framework that integrates the essential ecological and social processes in assessing restoration program implementation and ecosystem service provision.

Because ecological restoration programs (ERP) have been on the rise worldwide, restoration ecology—the science of practicing ecological restoration (ER)—has gained broad recognition (Aronson et al. 2010; Hobbs 2007). Meanwhile, socioeconomic scholars have been fervently promoting the concept of payments for ecosystem services (PES)[1] as an innovative approach of using economic incentives to address the loss of valuable ecosystem services (Wunder et al. 2008a, b; Bulte et al. 2008). Furthermore, ERP and PES are inherently linked. As partially listed in Wunder et al. (2008a, b), ERP generally constitute the largest category of PES projects in terms of financial investment and spatial coverage. More importantly, from the scientific viewpoint, both ERP and PES should be part of the integrated process of sustainable ecosystem management. Of course, ideally, no matter what it is called or how it is approached, ERP and PES ought to each feature this integrated process in order to achieve their shared goal—ecosystem sustainability.

However, the reality is different. As will be discussed, the majority of restoration ecologists and socioeconomic scholars tend to dwell in their own "comfort zone" and concentrate on different, disciplinary facets of the same process of ER and ecosystem management (EM). Consequently, the languages and methods that the two communities use are far apart, and they have not adequately engaged each other formally in their research undertakings. Certainly, this situation is not conducive to the accomplishment of their common cause. The objective of this chapter is to make a case for more effective efforts in integrating ERP and PES and thus more substantive interdisciplinary collaboration in the science and practice of forest ER and EM.

According to the Society of Ecological Restoration (SER), ER is an "intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability" (SER International Science & Policy Working Group 2004). Put differently, "ecological restoration is the practice of restoring ecosystems as performed by practitioners at specific project sites, whereas restoration ecology is the science upon which the practice is based" (*ibid*). The practice of ER includes a wide range of activities—erosion control, reforestation, removal of non-native species and weeds, re-vegetation of disturbed

[1] It should be noted that while the terms 'environmental' and 'ecosystem' services are often used interchangeably in the literature, for the sake of the present article we refer only to ecosystem services—the human benefits derived from both natural and managed ecosystems.

areas, and reintroduction of native species, as well as habitat and range improvement for targeted species (Aronson et al. 2010; UNEP 2008).

The last decade has seen a proliferation of publications on restoration ecology and ecological restoration. In addition to the rapidly increasing number of articles in such journals as *Agriculture, Ecosystem and Environment, Conservation Biology, Environmental Management, Frontiers in Ecology and Environment, Journal of Forest Ecology and Management,* and *Restoration Ecology* (Aronson et al. 2010; Hobbs 2007), a growing number of books are beginning to form a formal corpus of restoration ecology. To name just a few, these books include *Foundations of Restoration Ecology* edited by Falk et al. (2006), *Ecological Restoration: Principles, Values, and Structure of an Emerging Profession* written by Clewell and Aronson (2007), and *Ecological Restoration: A Global Challenge* edited by Comin (2010).

At the same time, PES have come of age and become a topic of great scientific interest and wide policy relevance. As will be shown later, socioeconomic scholars have different perspectives on PES—some view ecosystem services (ES) as another type of commodity transacted in the marketplace with an emphasis on economic efficiency, while others stress the peculiarities of ES and even reject the idea of commodifying ES, and thus give more attention to distributional effect and the public good nature of at least certain ES. In addition to debating over the essence and essentiality of PES, socioeconomic scholars have attempted to characterize PES programs in terms of their design, financing, environmental effectiveness, community participation, and livelihood outcomes, including effects on poverty alleviation and income distribution. Since 2008, at least four special journal sections/issues have been published on PES—three in *Ecological Economics* alone [see "Payments for Environmental Services in Developing and Developed Countries" in 65(4), edited by Wunder et al. (2008a, b); "Payments for Ecosystem Services: Reconciling Theory and Practice" in 69(6), edited by Pascual et al. (2010); and "Payments for Ecosystem Services: From Local to Global" in 69(11), edited by Farley and Costanza (2010), and one in *Environment and Development Economics* (see "Payments for Ecosystem Services" in 13(3), edited by Bulte et al. (2008)].

However, today the basic fact remains that despite the underlying nature of ER and EM as a coupled human and natural process, restoration ecologists have by and large focused on issues on the biophysical side, while socioeconomic scholars have concentrated on problems of the human dimension. As a result, real integrated studies are still the exception rather than the norm. Certainly, it is true that some experts on both sides have acknowledged the importance of the other side, articulated ways of pursing research that integrates both sides, and engaged their colleagues in productive interdisciplinary endeavors. But if ER and EM cannot be approached and explored as coupled processes, sustainability is difficult to accomplish (Reid et al. 2010). That is, without adequate attention to the socioeconomic elements, ERP cannot be effectively initiated and implemented; likewise, without sufficient incorporation of the biophysical elements and processes, PES cannot even specify what should be paid for, whom should be paid, or how to make the payments.

Therefore, what this chapter sets out to achieve is to elucidate the potential limitations in the current ERP and PES research and thus call for truly integrated and more relevant studies to provide effective guidance to ER and EM. To that end, the authors' narrative and arguments will draw extensively from what other scholars have voiced and pursued so far. In the following sections, the primary research developments and bodies of literature in ERP and PES as well as in studying the social-ecological systems will be reviewed first. Next, a systems framework that integrates social and ecological processes will be proposed, which will then be used to analyse China's recent experience in converting degraded cropland in order to illustrate the need for and possible ways of treating both ERP and PES as part of an integrated process of forest ER and EM. Finally, some closing remarks will follow.

9.2 Developments in Restoration Ecology

As emphasized by Comin (2010, p. xx), "Social and economic factors are as important as scientific and technical factors, or maybe more, and need to be integrated into restoration projects". Other scholars further noted that ER can be viewed from different perspectives (Clewell and Aronson 2007, p. 7). From an ecological perspective, it is an intentional activity that initiates or accelerates ecosystem recovery with respect to species composition, community structure, ecological function, and suitability of the physical environment to support the biota and connectivity of the surrounding landscape. From a socioeconomic perspective, ER recovers flows of natural goods and services of economic consequence that functional ecosystems provide to society. From the perspective of personal and cultural values, ER renews our relationship with nature in the realms of aesthetics, personal fulfillment, and shared experience and meaning. In a nutshell, ER represents an integrated biophysical and socioeconomic process.

A recent study by Aronson et al. (2010) has evaluated a large sample of the academic literature—1,582 peer-reviewed papers dealing with ER, published between January 1, 2000 and September 30, 2008 in 13 leading scientific journals[2]—"to determine whether links are made explicit between ER, society, and public policy related to natural capital". Their results suggest that restoration practitioners are failing to signal links between ER, society, and policy, and are underselling the evidence of the benefits of restoration as a worthwhile investment

[2] The scrutinized journals include *Agriculture, Ecosystem and Environment, Biological Conservation, Conservation Biology, Ecological Economics, Ecological Engineering, Environment and Development Economics, Environmental Management, Frontiers in Ecology and Environment, Journal of Applied Ecology, Journal of Arid Environments, Journal of Forest Ecology and Management, Restoration Ecology, and Water SA* (South Africa).

for society. Strikingly, a significantly lower proportion of papers from *Restoration Ecology* (2.7 %) than from the other 12 journals (10.5) addresses or refers to PES (p. 149). The authors thus concluded: "The existence of a gap between research on ER and the rest of society is substantiated…. More broadly, the concept of explicitly linking ecosystem services to beneficiaries of ecosystem restoration, and demonstrating their values to society, has only recently begun to enter the mainstream academic literature on the science and practice of ecological restoration (p. 150)".

They speculated that there are two plausible reasons for this: (1) the members of the research community involved in ES are isolated from those in the restoration field, and vice versa; (2) those involved in developing economic development pathways generally have overlooked the value of conserving ecosystems, and restoring natural capital through ER, as catalysts for economic development…. So, they further noted that "Often, the only—and usually very weak—link between restoration research and practice, on the one hand, and policy implications, on the other, were researchers' recommendations—rather than any specific or concrete indication of actual policy impact…. Ultimately, the 'human choice' factor—which is critical to the successful implementation of conservation goals and restoration outcomes—must become a bigger part of the focus of those who conduct ecological restoration research".[3]

Clewell and Aronson (2007, p. 7) elaborated that "Stakeholders should have ample opportunity to contribute to project planning, implementation, and later to the stewardship of the restored ecosystem. The benefits of restoration should…sustain or improve people's well-being—whether individual, cultural, or socioeconomic—and their ecological security into the indefinite future". In *The Recent Double Paradigm Shift in Restoration Ecology*, Temperton (2007) carefully remarked that "The synergistic interaction between the academic and the practical is not only a laudable aim in itself but is fast becoming a necessity if we are to be able to adequately deal with the current environmental challenges faced on a global and regional scale… It is becoming increasingly clear as restoration projects increase in quantity, size, and complexity that we need expertise and adaptive co-management on all levels for truly successful restoration…. There is an emerging sense that we as ecologists can no longer leave all the political and socioeconomic issues of restoration and conservation to the practitioners, managers, and politicians (p. 345)".

In "*Science, Art, or Application—the 'Karma' of Restoration Ecology*", Halle (2007) also acknowledged that the human dimension is a "missing peculiarity that

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[3] Interestingly, after this article had been drafted, the authors were made aware of yet another recent review of restoration ecology by Brudvig (2011). In that chapter, he noted that "Past work has been overwhelmingly focused on site-level restoration, with assessment at the species-level of biodiversity. Relatively little effort has been directed toward understanding links between restoration and landscape processes or factors (such as land-use legacies, authors' note) that determine historical contingency, nor has biodiversity been frequently assessed at the functional or genetic biodiversity levels (p. 5)".

makes ER distinct from natural succession". So, there is a need "to add socio-economic decisions as an additional pathway of impact…. What system is expected to emerge from restoration efforts is indeed not a solely scientifically driven decision, but is at least as much affected by the agreement among stake-holders with different interests as well as by economic constraints (p. 360)".

To sum up, a clear consensus has emerged among restoration ecologists that it is both necessary and beneficial to conduct research that integrates biophysical and socioeconomic components of ER. Doing so will make the science of restoration ecology more relevant and the practice of ER more effective.

9.3 Progress in Socioeconomic Science

According to Farley and Constaza (2010), socioeconomic scholars hold at least two distinct perspectives on PES, which seemingly parallel the conflicts between environmental economics and ecological economics. The environmental economics approach, as described by Engel et al. (2008), prioritizes economic efficiency and tries to 'force' ES into the market model. In contrast, the ecological economics approach, as outlined by Muradian et al. (2010), focuses on the multiple goals of ecological sustainability, just distribution, and economic efficiency, and favors a variety of payment mechanisms to achieve them, both market and non-market.

Wunder et al. (2005) defined PES as (a) a voluntary transaction where (b) a well-defined environmental service (ES) or a land use likely to secure that service (c) is being 'bought' by a (minimum one) service buyer (d) from a (minimum one) service provider (e) if and only if the service provider secures service provision (conditionality). Later, Engel et al. (2008, p. 664) rephrased this concept by stating that there are at least three necessary conditions for the design of a 'genuine' PES scheme: (a) the relationship between the type of land use being promoted and the provision of the ecosystem service must be clear; (b) stakeholders must have the possibility to terminate the contractual relationship (it is a voluntary transaction); and (c) a monitoring system must accompany the intervention, in order to ensure that the provision of services is taking place (additionality and conditionality of payments). Bulte et al. (2008) further stressed that PES programs aim to harness market forces to obtain more efficient environmental outcomes.

However, a number of experts have expressed their concerns and/or reservations with the PES definition given by the aforementioned studies. Among others, Muradian et al. (2010) formally presented an alternative approach to the PES definition that gives special emphasis to institutional and political economy issues. They argue that the pure market approach dominating the conceptualization of PES cannot be easily generalized and implemented in practice, since a prescriptive definition of PES that excludes the bulk of PES cases can be deemed at least flawed. Furthermore, dividing PES into 'genuine' and 'PES-like' can cause a mismatch between theory and practice, given that practitioners may often feel the frustration of not meeting theoretical expectations. By contrast, incorporating the complexities related to uncertainty, distributional issues, social embeddedness, and power relations permits acknowledging the variety of contexts and institutional settings in which PES operate. Therefore, Muradian et al. (2010) insisted that their alternative should be more appealing to PES practitioners, since it allows some key sources of complexities that they usually deal with on the ground to be more easily understood. As such, "a more inclusive and reflexive dialogue is needed between scholars and practitioners and there is a need to reconcile both theoretical and practical views using alternative notions of PES (p. 1202)".

In terms of PES design, Muradian et al. (2010) claimed that the approach advocated by Engel et al. (2008) puts great emphasis on reducing transaction costs, allocating property rights and establishing bargaining processes between those who own or manage the natural assets and/or their associated services (i.e., ES providers) and those who are willing to maintain or enhance the provision of such services through a payment (i.e., ES buyers). It is worth noting that the land ownership and use rights as well as the right to commercialize services may be hard to come about in developing countries. Vatn (2010) further pointed out that a wide variety of PES cases depend on state and/or community engagement, and therefore may not be considered as voluntary market transactions, at least from the buyer's point of view. And even if private transactions occur, sometimes the voluntary condition is not met. Examples include watershed-level PES schemes in which 'upstream' land managers are rewarded for improving their land use practices, but in which water users may not even be aware of paying higher water fees for PES.

Moreover, ES are often not fully defined, and PES tend to be implemented without previously establishing a clear-cut causal relationship between land use practices and the expected enhancement of the targeted ES. As a result, the efficiency of PES can hardly be demonstrated in certain cases. Also, many PES cases in developing countries fail to meet the conditionality criteria. Wunder et al. (2008a, b) acknowledged that many initiatives were either loosely monitored or not monitored at all, payments were up front instead of continuous, and payments were made in good faith, rather than being truly contingent on service provision. Usually, monitoring tends to be restricted to checking compliance with the promoted land use changes, instead of verifying changes in the actual provision of the targeted ES.

Another feature of the early PES conceptualization is its distinctive separation between efficiency and equity considerations, which suggests that PES must be considered primarily as instruments for improving the efficiency of natural resource management and not necessarily for alleviating poverty (Pagiola et al. 2005, p. 239). This vision renders effects on poverty reduction as positive 'side effects'—the poor should be targeted, however, as long as their inclusion does not imply efficiency losses. This may be attained in some cases, as demonstrated by Pagiola et al. (2008), who noted that in Nicaragua poorer landholders have been able to participate as providers of ES derived from silvopastoral biodiversity practices, thus benefiting from the scheme. However, the evidence regarding the effects of PES schemes on poverty alleviation remains mixed. For instance, in the PES scheme for forest conservation in Costa Rica—possibly the most well-known PES scheme in Latin America—most ES providers are relatively well-off landholders.

Similarly, in a review of eight other PES initiatives in Latin America, Grieg-Gran et al. (2003) found that some initiatives discriminated against poor smallholders because formal land tenure titles were required to access payments. Corbera et al. (2009) also reported that households with limited land endowments encounter difficulties in participating in a carbon forestry project in southern Mexico. Nonetheless, the significant interest that can be observed towards PES in the policy arena may be explained in part by the expectation that they may serve the dual goals of both ecosystem protection and poverty alleviation. Practitioners (governmental and non-governmental organizations and many others), particularly in developing countries, are often confronted with the need to meet these two goals at the same time, and frequently cannot skip taking equity and fairness into account when designing PES. Consequently, Muradian et al. (2010) argued that efficiency and equity considerations are in practice usually intertwined; and practitioners will increasingly face the challenge of having to link PES schemes with rural development programs.

Finally, the PES proponents may be reminded to not fall into “the panacea traps” by falsely assuming that all problems of resource governance can be represented by a small set of simple models and that the contextual details, including resource conditions and the preferences and perceptions of resource users, are the same (Ostrom et al. 2007). Some scholars have already raised the concern that “the flurry of interest in ecosystem markets supplied by restoration is out of step with the science and practice of ecological restoration, and so it is obscuring the fact that restoration projects…are not providing all the services of healthy ecosystems (Palmer and Filoso 2009, p. 575)”. Therefore, “until there is a sound basis for linking restoration actions to changes in biophysical processes and ecological features that result in the delivery of specific ecosystem services, restoration-based markets and trading schemes are a risky business (p. 576)”.

The above contentions over the definition and expectation of PES among scholars highlight the importance of how we perceive ES as well as the preliminary status of research in this area. Are ES nothing but the same as conventional commodities? Given their underlying biophysical characteristics, it is obvious that they are different. As such, the idea of integrating ES into markets and treating PES like any other market transaction seems short-sighted and flawed. But even those who hold a broader perspective on PES rarely have articulated clearly how they can better integrate the biophysical and human dimensions of PES, including ES measurement and monitoring. Indeed, many scholars tend to do so simply in an abstract setting, with much of the biophysical specifics being neglected. In this regard, one notable exception these authors are aware of is Constaza and his colleagues. For instance, Farley and Constaza (2010) emphasized that the ecological economics approach to PES seeks to adapt economic institutions to the physical characteristics of ES by prioritizing ecological sustainability and just distribution and by deploying a transdisciplinary methodology.

9.4 Advancement in Social-Ecological Integration

If we move beyond the narrowly focused inquiry of ERP or PES, what appears in sight is the growing interest and significant progress in understanding the social-ecological systems (SES), and the coupled human and natural processes. Back in the early 2000s, some experts already observed that the initiatives of ER and PES are generating demand for, and spurring the development of, integrated ecological-economic-social approaches to managing ecosystem assets, and the potential for such approaches is tremendous (Daily et al. 2000). Later, Carpenter et al. (2009) articulated that sustainability science is motivated by fundamental questions about the interactions of nature and society as well as compelling and urgent social needs. They argued that relevant research topics often transcend the issues of traditional academic disciplines and focus instead on complex interactions of people and nature. In addition, progress in sustainability science does not resemble the usual paths of scientific inquiry, where action lies outside the domain of research. Instead, scientific inquiry and practical application are commingled. Explicit models of coupled SES are thus essential for research, synthesis, and projection of the consequences of management actions.

Carpenter et al. (2009) further noted that the gaps in knowledge that exist today cannot be addressed through un-coordinated studies of individual components by isolated traditional disciplines. Instead, a new kind of interdisciplinary science is needed to build an understanding of SES. To understand changes in ES, the interactions of social and ecological constituents of the earth system must be considered. Discipline-bound approaches that hold one component constant while varying the other lead to incomplete and incorrect answers. Although many important questions of basic interdisciplinary science must be addressed, here we are most concerned with the problem-solving aspects of social-ecological research.

Ostrom and Cox (2010) went on to articulate that "Settings for human-environment interactions are complex. They are composed of diverse ecological systems (including lakes, rivers, fisheries, forests, pastures, the ocean and the atmosphere), as well as human-engineered systems (including roads, irrigation systems and communication networks). Finding ways to sustainably govern and manage these systems has become ever more difficult as they have become increasingly interlinked, and as the size of human population and the level of economic development have both increased. Addressing this complexity must in turn overcome historical academic divisions between ecology, engineering and the social sciences, the tendencies of social scientists to build simplified models of complex systems in order to derive ideal types of governance, and an overreliance on a limited set of research methods to study social and environmental systems (p. 451)". These authors also made it clear that "To do the social-ecological work that is needed will require knowledge and perspectives from scientific disciplines that are frequently isolated from one another. It will also require a novel integration of methodologies to study social and environmental processes. Enabling scholars from multiple disciplines to share a common framework for diagnosing the sources of diverse environmental problems will take time and effort within a dedicated research program (p. 458)".

A more recent study by a group of investigators (Collins et al. 2010) of the Long Term Ecological Research (LTER) program, which is supported by the US National Science Foundation, has further stressed the notion that "a more integrative approach to environmental science, one that bridges the biophysical and social domains, is sorely needed (p. 1)". Thus, they have proposed "an iterative framework, 'Press-Pulse Dynamics' (PPD), that integrates the biophysical and social sciences through an understanding of how human behaviors affect 'press' and 'pulse' dynamics and ecosystem processes (p. 1)". In their view, such dynamics and processes influence ecosystem services—thereby altering human behaviors and initiating feedbacks that impact the original dynamics and processes. Based on this new perspective, the authors have called for transforming the LTER program into a Long-Term Social-Ecological Research one.

As to the notion of coupled human and natural systems CHANS, Liu et al. (2007) emphasized the reciprocal interactions and feedbacks—both the effects of humans on the environment and the effects of the environment on humans. Thus, understanding within-scale and cross-scale interactions between human and natural components (e.g., how large-scale phenomena emerge from local interactions of multiple agents and in turn influence local systems) is a major challenge for the science of CHANS. In their view, the main characteristics of CHANS include complex couplings (among organizations, across space, and over time), nonlinearity and thresholds, surprises and uncertainty, legacy effect and time lags, resilience, and heterogeneity.

Studying these complex characteristics has practical value for sustainable environmental and natural resource management and governance. For instance, CHANS challenge traditional planning and management assumptions and strategies for natural resources and the environment. According to Liu et al. (2007), most policies in place today will not lead to sustainable outcomes. Some emerging new policies, such as ecosystem-based management in oceans and coupled land-sea ecosystems, seem to move in the direction of sustainability and need to be encouraged, implemented, monitored, and revised where necessary. The success or failure of many policies and management practices is thus based on their ability to take into account the complexities of CHANS. As an example, without considering cross-boundary effects, forest harvests in the upper reaches of river basins often result in serious soil erosion and floods downstream. Also, assumptions regarding climate variability and extreme events that do not take into account the uncertainty often result in lack of preparedness and effective response. Therefore, managing CHANS effectively requires not only consideration of all major natural components but also coordination of human components as well as their interactions.

From the above brief overview, it becomes evident that the scientific community has actually realized the importance of SES and CHANS and developed operational frameworks to put them in practice in sustainable ecosystem management. Undoubtedly, these advances are pertinent to the science and practice of ERP and PES and thus important to forest economics.

9.5 Examining China's Recent Experience with a Systems Approach

Below, we will first outline a systems approach to analyzing ER and then use it to examine China's recent land restoration experience. The above literature review suggests that an essential step in formulating a systems approach to ER assessment is to effectively incorporate both biophysical and socioeconomic components and processes into it. Clearly, the impacts of an ER program are manifested in both environmental and socioeconomic changes. As originally discussed in Yin (2009), environmental changes are reflected in ecosystem productivity and stability, such as the status of biological diversity, soil erosion, and carbon storage; socioeconomic changes are represented by such indicators as cost effectiveness, labor transfer, and livelihood enhancement. Thus, an integrative assessment must embrace both the environmental and socioeconomic changes; further, they must be investigated together under substantive interdisciplinary collaboration.

Moreover, assessing the ER impacts and effectiveness must be conducted at multiple scales. This is because all issues cannot be well examined at a single scale. For instance, some socioeconomic impacts can be easily detected at the household or village level; however, ecological impacts, determined by the integrity of ecosystem functions, must be assessed at least at the watershed scale. Certainly, place-based and regionally focused work is more adequate to accommodate integrated socioeconomic and ecological investigations (Clark 2007). Indeed, a regional-level assessment is more sensible given the personnel, financial, and time constraints involved in a national assessment on the one hand and the impossibility to answer most relevant questions with local-level studies on the other. In addition, research at different scales may lead to different findings that can be complementary (Turner et al. 2007). Figure 9.1 is a sketch of our systems approach to ER assessment.

Now, let us illustrate the relevance, pathways, and examples of applying this approach to assessing ER using China's recent experience—the Sloping Land Conversion Program (SLCP)—as an example. The SLCP was initiated by the Chinese government in 1999 with the environmental goals of reducing soil erosion and desertification and increasing the country's forest and grassland cover by retiring steeply sloping and marginal lands from agricultural production. Also known as Grain for Green and Grain to Green, it is the largest land retirement program in the developing world, with the target of converting around

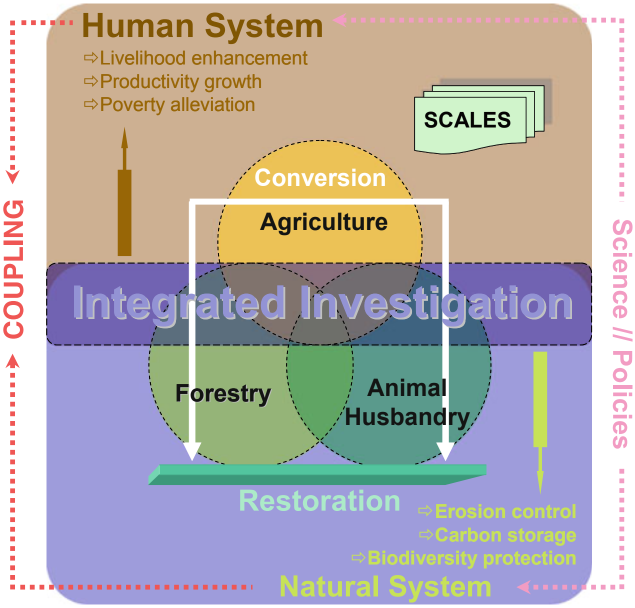

Fig. 9.1 An illustration of the proposed systems approach to ecological restoration assessment. *Source* Yin and Zhao (2012). Ecological restoration programs and payments for ecosystem services as integrated social-ecological processes. *Ecological Economics* 73: 56–65. *Note*. The diagram shows that we will assess the relevant impacts of China's ERPs and explore the primary linkages between ecosystem services and human wellbeing at the proper spatial and temporal scales of an integrated research framework

14.67 million ha of cropland to forests (4.4 million of which is on land with slopes greater than 25°) by 2010 (Bennett 2008). Meanwhile, the program also has the stated objective of poverty alleviation and assisting farm households to shift to more sustainable economic activities (State Forestry Administration 2003).

The SLCP has thus been subsidizing farmers to convert sloping cropland and other degraded fields to forest and/or grass covers in 25 provinces during the last decade (Xu et al. 2006; Yin 2009). In addition to an annual cash outlay of 300 yuan[4] per ha for purchasing seeds and seedlings and tending activities, farmers initially received a grain subsidy of 2.55 t/year per ha of retired cropland in the Yangtze River basin and 1.50 tons/yr per ha in the Yellow River basin. The duration of subsidy is eight years if environmentally benign trees (species mainly providing ecological functions and services) are planted; five years if commercial trees (species producing timber, fruits, nuts, and other products) are established; and two years if grassland is rehabilitated. Because of the dwindling of grain reserves, the central government later decided to stop the food subsidy; instead, monetary compensation is provided by setting the grain price at a constant level of

[4] 1 US dollar = 6.3 yuan, according to the latest exchange rate.

1.40 yuan/kg (Yin and Yin 2010). Since many participating farmers were still facing poverty and had difficulty finding alternative job/income sources, in 2007 the State Council decided to extend the program until 2020. Its total investment is projected to reach 431.1 billion yuan (Yin and Yin 2010).

Targeting of land conversion starts with quotas distributed from the central government to the provinces, followed by subsequent distribution down through counties, townships, and finally to participating villages. Program compliance is defined in terms of the quality, type, and survival rates of the trees/grasses planted on the enrolled land, with survival rates being adjusted for regional conditions (Yin and Yin 2010; Bennett 2008). Notably, the linkages between cultivation of sloping and fragile land and the frequency/severity of floods are not as clear-cut as commonly presumed, nor is it that afforesting such areas will be the most effective means of reducing erosion or desertification.

There are a number of issues that should be carefully considered before such a huge program is launched as well as during its implementation. First, while the direct engagement of households as core agents of program implementation sets a new direction in managing China's strained natural resources, several features of the program hark back to policies and mindsets of decades past (Yin et al. 2005; Bennett 2008). These include the top-down, simplified contract structure, the lack of sufficient consultation with local communities and rural households to identify their needs and constraints, and the campaign-style political mobilization aimed at reversing, in one decisive thrust, a range of adverse environmental outcomes stemming from a variety of factors. Given this situation, it seems not quite appropriate or adequate to simply call the SLCP a PES project. In particular, if no sufficient attention is given to the complexity involved in the program (as further noted below), it is less productive no matter what it is called—PES, Grain for Green, or Grain to Green.

Second, numerous interventions exist in this type of ER project, ranging from outright conversion of degraded cropland to forest/grassland to gradual ecological recovery via combined farming, herding, and/or tree-planting practices, and from uniform to differential designs and subsidies based on local conditions. But what has been implemented under the SLCP is predominantly the outright conversion of degraded cropland to forest cover, with banning of farming and/or herding activities and a monolithic standard of compensation (Yin et al. 2010). Are these practices the most effective ones? The answer is: Probably not. Regardless, though, the fact is that the choice of these practices has not only caused drastic alteration to the local production modes and livelihoods, but also has been ineffective in mitigating runoffs and erosion in many instances due to the poor ground cover resulting from planting only tall trees. As observed by Li et al. (2010), what is central to mitigating runoffs and erosion is improved ground cover of trees and/or grass, rather than just land retirement itself. To improve ground cover, however, satisfactory survival and stocking rates are crucial. But Li et al. (2010) demonstrated that along with cropland set-aside, a large amount of unused land plots—abandoned cropland with only sparse ground cover—has emerged. These plots have in turn led to higher runoff and erosion rates in the short run, compared to similar land for growing annual crops.

A related phenomenon has been that in contrast to its enthusiasm for the planting of trees, the State Forestry Administration, which is in charge of implementing the program on behalf of the central government, has shown less interest in other measures, such as grassland recovery and check-dam formation, even if such measures are better suited in certain circumstances. Observers have voiced their concern that planting tall trees in semiarid and arid northwestern regions may not work well in that environment (Normile 2007; Cao 2008). They asserted that planting poplars as a major species for afforestation in those regions is problematic given the limited precipitation. In many instances, it is hard to establish the trees; and wherever they are established, their deep root system can hemorrhage ground water through transpiration, lowering the water table and making it harder for native grass and shrubs to survive. One may also add that forest management activities ensuing tree planting and regeneration, such as tending and thinning, have not been well incorporated into the program; furthermore, this issue has been confounded by the high initial planting densities driven by farmers' desire to fulfill the government's requirement for high survival rates in order to claim their subsidies sooner (Wang et al. 2007; Yin et al. 2005). As a consequence, the tree growth rate tends to be low after canopy closure, and thus, forest quality, let alone ecosystem functionality, has not been very satisfactory. This, in turn, makes the established forests vulnerable to fire and pest attacks in the long term. More emphasis should thus be placed on the quality of tree planting and the need for follow-up management.

Moreover, it seems that the policy proscriptions by the Chinese government have been aimed at simply removing farmers from land designated for forestation and placing them into non-agriculture forms of employment close to or in urban areas, or nowhere at all. Instead of moving land management from one extreme (extensive cultivation) to another (extensive forest) without consideration of alternatives, more complex scenarios can be developed by merging both ecosystem services and economic/livelihood services. In fact, evidence indicates that many communities, against the directive of the local authorities, have adopted agroforestry regimes by continuing the growth of annual crops and planting more commercially valuable trees on retired farmland (Yin et al. 2005). And it appears that these regimes have brought about nontrivial monetary benefits, while effectively mitigating runoff and erosion.

To be sure, the program payments are on average quite generous, even by international standards (Uchida et al. 2005). And over the long term, the participating rural households will benefit from the future environmental services provided by the program, including the hard-to-estimate future revenues from harvested timber, in addition to the downstream recipients of watershed services (Bennett 2008). But it is unclear why the standards, durations, and specific restoration measures cannot be localized and more flexible, why community's interests and stakes have not been well incorporated into the program design and implementation, and why the government did not conduct enough pilot projects before the SLCP was formally launched.

Also, the early shortfalls in delivered subsidies are in part symptomatic of a key design problem: poor administrative budgeting. In general, program coordination, inspection, and subsidy delivery for millions of plots is burdensome and costly, and yet the original SLCP plan dictates that local governments bear their own implementation costs. Only after mounting complaints as well as delayed executions and inspections by the local agencies has the central government made the necessary adjustments (Yin and Yin 2010). Naturally, this implies that the program may not be obtaining the efficiency gains promised by the so-called PES scheme over the traditional command-and-control approaches via the use of a market-based mechanism for participation.

Additionally, the success of the program depends not only on the program stipulations, but also on other related policies and market conditions (Yin et al. 2005). For instance, policies concerning rural land and labor markets can alter the opportunity cost of land use and eventually influence the incentive of farmers to participate in the program and the likelihood of their reconversion of the retired cropland (Yao et al. 2010). Similarly, the way local farmers manage their livestock, be it open grazing, fenced rotation, or confinement feeding, has a major impact on the reestablished vegetation and thus the ultimate outcome of the restoration. It is thus important to explore the interactions of different policies to properly achieve and assess the effectiveness of the program. In this regard, it has now become clear that the extent of the local implementation, the status of the local economy, and the commitment of local politicians all play critical roles in ensuring the program's success and promoting off-farm employment and thus labor transfer (Yao et al. 2010). Therefore, more work is needed to determine where and to what extent the planned activities can be allocated and how a coherent and consistent incentive structure as well as a supportive policy environment can be established in implementing the SLCP.

The experience of Wuqi county in northern Shaanxi province is useful in illuminating the issues discussed above. To achieve rapid re-vegetation of the retired cropland, the county decided to use *Hippophae rhamnoides*, a native, drought-tolerant shrub species, as its dominant choice for planting (Wuqi Bureau of Land Restoration 2009). Indeed, the massive amount of retired cropland (over 80 % of the county's total) became green in a matter of 3-4 years, and the change can even be clearly detected from satellite imagery (Yao et al. 2010). Unfortunately, this species has limited economic value to local farmers, other than being a good feedstock for sheep/goats. And it can become a fire hazard once the stand has lost its growth vigor. As a consequence, the county government had to add tall trees of higher economic value to improve the stands, leading to a large sum of additional expenditure. However, because the financial condition of this county was much stronger than its neighbors and its government was willing to use the resources at its disposal to cover the costs, it was able to do so. Unfortunately, most local governments do not have the financial and political commitments that

Wuqi does, which calls into question the effectiveness and sustainability of the program.

Meanwhile, the cropland retirement and open grazing bans in Wuqi, while beneficial to improving ground cover and reducing erosion, have resulted in shock waves to the local economy (Yao et al. 2010). Again, thanks to the local government's willingness and capacity to provide much needed technical and financial assistance, the ripple effects have been greatly mitigated—while a large number of rural laborers were transferred into off-farm and off-village economic activities, farming productivity was actually increased substantially (Yao and Li 2010). This case has some significant implications. First, it is necessary to make plans and take actions in dealing with the induced changes to the local economy and society. Second, it is beneficial to view the ERP from a longer-term perspective by looking beyond the immediate task of having trees planted or vegetation recovered and thinking through how to maintain and improve the recovered vegetation and thus increase the ES provision in the long run. Also, it is worthwhile to sort out how to alleviate the hardships the local people may suffer and enhance their livelihoods throughout this transitioning process.

In investigating the SLCP targeting efficiency, some researchers have used a single biophysical attribute—the cropland steepness—as a proxy for the environmental condition (e.g., Xu et al. 2004; Uchida et al. 2005). As the environmental benefits and economic costs of the program vary across the landscape due to differences in climate, topography, land cover, and management practices, it is unlikely that slope steepness alone is a sufficient proxy for erosion severity or any other ecological condition. While it is reasonable to use such a crude proxy, particularly during the early years of assessment when ecological and hydrological observations were not available, it should be made clear that this type of indicator has only limited validity and thus direct observations of soil erosion, water runoff, and other biophysical changes must be made. In an attempt to address this deficiency, experts have formulated a feasibility index or a suitability system for cropland set-aside and re-vegetation (Long et al. 2006; Wang et al. 2007), based on both biophysical and socioeconomic conditions. Related to this situation is the tendency to ignore the fact that rural households in China typically have scattered cropping plots of tiny sizes (<0.2 ha in most cases), making the inferences regarding which plot should or should not be enrolled of little use to gauging the program effectiveness at the landscape level. Viewed in this light and from an ecosystem perspective, it may well be justifiable for the local agencies to select certain plots with less steepness and easier access into the program for the sake of feasibility and practicality in its implementation.

Studies have also made it clear that flexible payment mechanisms and competitive selection processes (such as auction) would improve the cost effectiveness of the programs (Uchida et al. 2005; Yin and Yin 2010). It is thus suggested that the SLCP may adopt the bidding process used elsewhere. However, it should be recognized that perfect targeting typically cannot be achieved in practice since transaction costs are involved in collecting and processing information. One problem that arises from the bidding mechanism is the behavior of strategic bidding, which affects the rental rates. Further, the bidding mechanism may not be a realistic option in rural China where the administrative costs to set up such a mechanism would be fairly high (Xu et al. 2006). Therefore, the adoption of a more practical payment scheme, such as differentiating compensations based on the benefits of certain plot type, could be pursued. So far, however, little empirical work has been done to evaluate the feasibility and effects of those alternative mechanisms.

The above discussion of China's recent experience and lessons in initiating and implementing the SLCP highlights the myriad deficiencies and challenges of the current restoration schemes and the acute need for improved program design and implementation and thus for assessing the complex issues within a combined natural and human systems framework. As repeatedly demonstrated, it is often hard to separate ecological issues from socioeconomic ones in the real world, and analysts from different disciplines and practitioners with different expertise must work together to make the ERP more effective and efficient. Readers interested in some early efforts along this direction can refer to Yin (2009).

9.6 Concluding Remarks

This chapter was motivated by the authors' basic observation that while the science and practice of ERP and PES need to integrate the biophysical and socioeconomic components and processes, the divide between these components and processes remains wide and prevalent. This is so despite the fact that by working together to deal with the relevant issues in a systematic way, ERP and PES research can greatly contribute to our understanding of the complex linkages and causal relationships between various factors involved in ER and EM. To make a case for truly integrated inquiries, the authors began with a brief review of the scientific developments in restoration ecology, environmental and ecological economics, and studies of SES and CHANS. Then, a systems approach to ER assessment was outlined and its relevance and potential uses were illustrated using China's recent experience of retiring and converting sloping cropland and other degraded fields. It was hoped that these efforts in combination would highlight the challenges and opportunities in the current ERP and PES research and thus convince ecologists, economists, and scientists in other disciplines to reach out to one another in undertaking more meaningful collaboration in order to move their academic enterprise forward.

Of course, it is our sincere desire that steps taken and advances made in this area will also add new perspectives, tools, and contents to forest economics. Indeed, forest economic and policy research has been looking for more integrated, systematic analyses (Kant 2011). The approach we have articulated here can be applied to many other issues related to forestry, including the driving forces and environmental consequences of land use and land cover changes, forest ecosystem service evaluation, sustainable forest management, and climate change adaptation and mitigation. Further, this approach is flexible in accommodating the particular subject matter of interest. The critical elements of putting this systems approach into practice are to form teams of experts from different disciplines and to build comprehensive datasets and develop appropriate models, so that a holistic view of the subject matter can be formulated, the knowledge gaps bridged, the analytical modules assembled, and policy-relevant empirical insight derived. All of these require time, effort, and funding, and they may not be compatible and consistent with the current institutional setup and professional organization, among other factors. Therefore, concerted and sustained attempts must be made to enable this approach to take hold and bear fruit.

Nevertheless, as Carpenter et al. (2009) eloquently stated, the knowledge gaps in sustainability science cannot be addressed through un-coordinated studies of individual components by isolated traditional disciplines; instead, a new kind of interdisciplinary science is needed to build an understanding of social-ecological systems. And even though many important questions of basic interdisciplinary science must be addressed, here we are most concerned with the problem-solving aspects of social-ecological research. Reid et al. (2010) also pointed out that answering the questions related to global environmental change and sustainable development will require "reorientation toward new research that better allows science and society to address the needs of decision-makers and citizens at global, regional, national, and local scales… (p. 916)". Interestingly, they also advocated that "Research dominated by the natural sciences must transition toward research involving the full range of sciences and humanities. A more balanced mix of disciplinary and interdisciplinary research is needed that actively involves stakeholders and decision-makers… (p. 917)". The authors sincerely hope that scholars in different fields will respond to these calls for change.

Looking ahead, it is anticipated that as socioeconomic conditions are improved, more and more countries will initiate ER efforts given the large amount of degraded land on the one hand and the urgent need for maintaining and enhancing ecosystem conditions, functions, and services on the other. It is in this context that the authors have devoted a great deal of space to discussing the complex issues involved in China's SLCP. Of course, China can learn from its own experience and lessons, and many other countries can learn from China's experience and lessons. From China's experience and lessons, it can be seen that while it seems fashionable to call the SLCP a PES, Grain for Green, or Grain to Green project, these names do not accurately convey the essence of the project; its totality and complexity can hardly be reduced to a simple payment of some sort for ES, nor can it be adequately described by Grain for or to Green, or other fancy terms. It entails allocating a huge amount of public financial resources to subsidize the adoption of a series of restoration actions over degraded cropland by 15 million rural households in at least two decades. For any serious attempt to evaluate its performance and promote its ultimate success, attention must be given to the underlying challenges it has faced with a comprehensive perspective and approach, especially a basic willingness to incorporate the necessary biophysical and socioeconomic elements. In this regard, it is also true that in the absence of an effective monitoring system, there is limited ability to assess the influence of restoration efforts on ecosystem integrity and sustainability, and thus there is little basis for improving the performance of the SLCP or any other ERP or PES.

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Chapter 10
Economics of Multiple Forest Values and Life Cycle Analysis

Bruce Lippke, Elaine Oneil and Kevin Zobrist

Abstract As climate mitigation efforts transform the value of carbon with institutions creating incentives as well as regulating markets, avoiding unintended consequences becomes challenging. Life Cycle Inventory and Analysis (LCI/LCA) research tracks carbon and other services from the forest to products including displacement of fossil emissions when wood substitutes for fossil fuels or fossil intensive products. Incentives that do not target uses that displace the most emissions will likely steal the feedstock from less effective uses, increasing rather than decreasing emissions. We apply life cycle research to identify leverage points in reducing carbon emissions and their impact on old forest habitat as the ecosystem value most likely threatened by carbon mitigation incentives. Ethanol subsidies, forest carbon credits, and renewable energy standards steal the feedstock from higher leverage uses, while a carbon tax effectively penalizes the largest emitters. Either carbon taxes or incentives will affect the cost of sustaining critical habitat. Institutions need to consider life cycle implications to sustain forests and their multiple values. While a carbon tax provides the proper price signal with the highest reward for the greatest carbon emission reduction, increasing habitat values may be justified to support the production, maintenance and restoration of important habitat.

B. Lippke (✉) · E. Oneil
School of Environmental and Forest Sciences, College of the Environment,
University of Washington, 352100 Seattle, WA 98102, USA
e-mail: blippke@uw.edu

E. Oneil
e-mail: eoneil@uw.edu

K. Zobrist
Natural Resources Extension, Washington State University,
600 128th St SE, Everett, WA 98204, USA
e-mail: kzobrist@wsu.edu

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10.1 Introduction

Since the dawn of history forests have contributed multiple values to the advancement of society. It is mostly in the last century that the expanding industrial populations have raised concerns for declining habitat and biodiversity. Removing timber from forests through most of history was considered extractive, as forests regenerated naturally requiring no concerted management. Markets developed naturally by trading for the values forests produced including wood for fuel and higher values for structural materials contributing to shelter and a goods producing infrastructure. More recently markets developed for using residuals and chips for making paper and other fiber products. As markets for tradable products and services grew, so too did the incentive to invest in managing the forests to produce marketable benefits.

As more of the forestland was devoted to commercial uses of the forest there were declines in some habitat and species diversity. Some benefits are derived by common use and are not so easily marketed. Non-market benefits include services like clean air and water, carbon sequestration, aesthetics, habitat, biodiversity protection and fire avoidance. Pricing non-market benefits and services supplied by forests can be difficult because of their non-traded nature. However, these non-market values can be quite high as evidenced by governmental efforts to protect them.

Many of these non-market values have been analyzed in terms of what it costs to produce them relative to producing marketable products thereby providing an "opportunity cost" structure for producers that are willing to broaden the values being produced from the forest. This provides one important dimension of a decision support system if policy makers wish to incentivize the production of non-market benefits that have not historically been traded in the market. The value of these benefits to the consuming public is even more difficult to characterize but another important dimension needed for effective policies. In the United States of America (USA), with the introduction of the endangered species act some public benefit values have become the focus of regulatory attempts to protect them, frequently resulting in substantial cost increases to producers with negative monetary incentives to either protect or produce endangered species habitat.

While many tools have evolved in recent decades to incentivize non-market benefits, the central barrier has been the ability to source enough revenue to produce a market driven demand that would produce these benefits in competition with market priced products and services. But in spite of these developing tools, the recent focus on the importance of carbon mitigation has the potential to

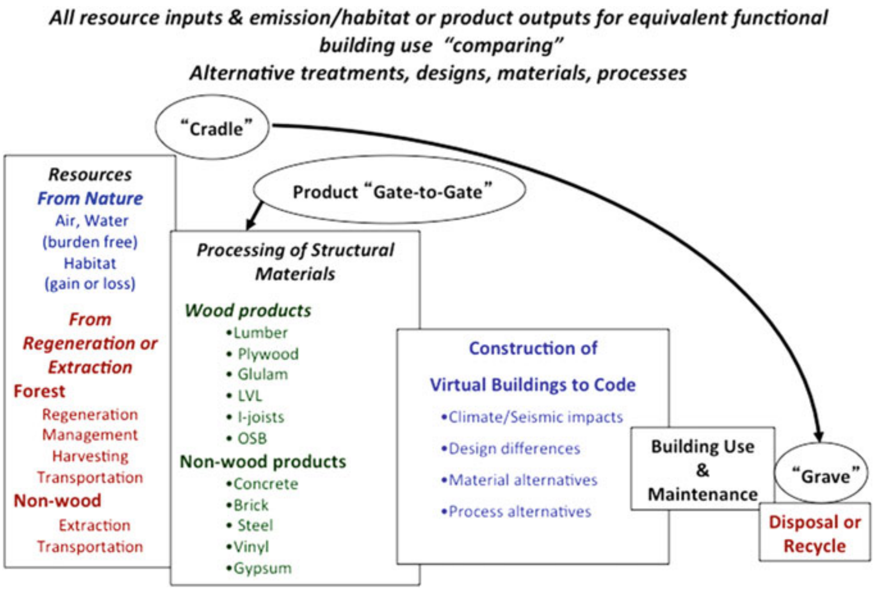

Fig. 10.1 Understanding the role of carbon from cradle to grave

dominate all other non-market benefits as the market value of fossil fuel, the dominant source of carbon emissions, is so large and critical to a functional economy. Forests play an important role in the global carbon balance raising many questions on how reducing carbon emissions may contribute to or compete with other market and non-market benefits. It is not enough to sustain a balance between timber markets and habitat or biodiversity, as the rising values of carbon can be expected to become a dominant driver. The focus of this chapter is to understand the role of forest management in contributing to carbon pools and offsets and how this can be expected to affect the increasing problem of maintaining a sustainable balance across many non-market benefits.

To understand the role of carbon from the forests one must first understand the impact on carbon, not just in the forest, but also in forest products or biofuels, and as substitutes for non-wood products that are generally more fossil intensive. Second, an understanding of the carbon impacts through the useful life of products, such as the building materials in housing and the end of their useful life by recycling, burning or land filling is required. Only by understanding the total value of carbon from "cradle to grave" can one consider at the same time how to think about managing for other values (Fig. 10.1). While an allocation of specific forests to produce specific benefits may be appropriate, when multiple benefits can be produced from the same forest it provides the opportunity for much greater efficiency in satisfying the many values generated from our forests. Forests have a substantial impact on the global carbon cycle; the important questions are how to reduce emissions while contributing as much as possible to other market and non-market benefits.

To motivate why carbon can be so important, we first characterize how several policies currently in vogue affect decisions, noting how easy it is for policy to cause unintended and counterproductive impacts. These examples provide justification for the importance of life cycle analysis in quantifying impacts. We track carbon as an important life cycle measure across every stage of processing quantifying all inputs and outputs. We identify a range of good to best practices for carbon mitigation. We then evaluate a wide range of policies that attempt to affect carbon outcomes and summarize how to avoid counterproductive impacts. We determine which among the non-market attributes may be complementary or competitive with growing timber for markets, for carbon mitigation objectives, or critical habitat as a good surrogate for other non market values. Since providing ecosystem services is still a new economic frontier, we cannot hope for optimum solutions but believe that by showing how to avoid making decisions that are counterproductive to multiple objectives, progress will be served. The combined value of benefits to the public and producers can be increased by managing forests for more than timber values. This chain of values includes not just the non-market benefits that exist in the forest but also includes avoidable downstream costs and the impacts of how the use of different products affects the environment. Finally we cross over from supply side methods that estimate the opportunity cost to produce non-market benefits to what can be learned about how society values some of these benefits, acknowledging that without market transactions estimates of willingness to pay for benefits may be useful for policy even though derived from a far from complete decision space in choosing among alternatives.

10.2 Why Carbon is so Important?

While international negotiations to reduce carbon emissions are ongoing, emissions continue to rise with little evidence of progress (Friedlingstein et al. 2010). US policy objectives to achieve energy independence given the high cost of importing so much oil, remain ineffective. To motivate the need to thoroughly understand the implications of actions that in effect provide incentives for mitigating carbon consider the following. The European Climate Exchange (ECX), a less than voluntary carbon market, trades carbon contracts valued at roughly \$20–30/ t of CO_2 while the Chicago Climate Exchange (CCX) operating as a voluntary market provided less than \$2/ t (\$2 mt CO_2) and closed in November 2010, lacking the volume that was anticipated under a carbon cap and market trade policy. Yet economic studies support the contention that carbon values will have to increase for any real success at meeting carbon mitigation objectives (Nordhaus 2001). If recent ECX values of \$25/mt CO_2 were truly monetized into markets it would pay a forest owner \$46/ t for the production of (dry-equivalent) wood. For a representative US Pacific Northwest sustainably managed stand that would generate \$250/hectare/year (\$250/h/y) of revenue on a 45-year rotation. Using a 5 % discount rate (inflation adjusted) that produces almost the same net present value

(NPV) return to the managed hectare as is currently being received from timber markets, thereby potentially doubling the return to forest management with expectations of further increases as carbon values rise. The incentives to increase carbon through tree growth may exceed the current value from growing structural wood used in buildings. The rules governing contracts are non-trivial and may monetize the value of carbon in the wood or restrict it by arbitrary contract definitions such as requiring permanence, hence the rules become critical links to success or failure in meeting intended objectives (Taylor et al. 2009).

As another illustration of the importance of carbon incentives and rule making consider the $0.51/gallon ethanol tax credit provided for corn ethanol by the US Congress. After several years of study it was determined that it takes 5 gallons of corn-ethanol to displace 1 gallon of gasoline or $2.60 to displace the 19lbs of CO_2 from combustion of the gasoline for an equivalent value on carbon mitigation of $295/tonne of CO_2, 10 times greater than the ECX value (100 times the CCX value). As a Congressional response to these findings, in the Energy Independence and Security Act, EISA 2007, (Sissine 2007), congress now requires a life cycle assessment of the benefits from synthetic fuels requiring minimum thresholds for reduced emissions relative to gasoline before the fuel meets federal standards. Understanding the life cycle implications of carbon is no longer just prudent, it is required, at least for synthetic fuel production. The lessons learned also infer that just what must be measured and how carbon credits or values are to be determined is critical.

Since deforestation in many developing countries has led to efforts to use carbon values as an incentive to end deforestation, which contributes to the loss of many other forest values beyond just carbon, the chain of impacts involves many non-market uses of the forest. In developed countries a similar effort has been focused on restricting carbon credits for use only to increase forest carbon and not extend the benefits to product uses that are defined to be non-permanent, in order to avoid overcutting the forest which has negative implications for other values like habitat. By leaving out the uses of forest removals that substitute for fossil intensive products like steel and concrete there will unfortunately likely be greater carbon emissions from using fossil intensive products than can be saved in the forest.

One cannot design effective incentive methods for carbon or other forest values without developing a thorough life cycle accounting system from the forest, through the processing of products and fuels, and their use such as in construction, building use, maintenance and ultimate recycling or disposal or reclamation of wastes for their energy value. Life cycle inventory (LCI) data of all inputs and outputs for every stage of processing, which includes all greenhouse gas (GHG) emissions has over the last decade been developed for a full suite of forest uses in conjunction with other primary products made publicly available through such databases as the USLCI database (NREL 2009). The data for US forests and products have been compiled by the Consortium for Research on Renewable Industrial Materials (CORRIM 1998) a 17-research institution not-for-profit consortium (www.CORRIM.org). Their data source is used here to demonstrate how to track forest carbon impacts across their many processing stages and end uses.

10.3 Tracking Carbon Across Stages of Processing and End Uses

Life Cycle Inventory data provides a snapshot of all inputs and all outputs for each stage of processing. While the LCI for processing a product such as lumber from logs occurs over a short time interval, for renewable materials the forest growth cycle may be quite long. In addition the product life cycle can be long and dependent upon end of life management options. In order to track carbon pools over time, each current process is attached to its time event producing a cross-section of every stage of processing as a function of time. The process portrays the impact of current technology, not predicted or past technology. Forest carbon pools are measured by samples of field inventory plots with simulations of future impacts produced from forest growth models. Product carbon pools and substitution pools are derived from manufacturing unit process surveys, which measure all inputs and outputs in manufacturing the primary product and any co-products. Alternative simulations can be produced characterized by assumptions altering technology change such as changes in management practices, mill technology or end of life options.

10.3.1 Forest Carbon Pools Under Alternate Forest Management Regimes

As forests grow they store carbon removed from the atmosphere in biomass providing a carbon storage pool of removed atmospheric carbon. As forests age, they reach carrying capacity maxima resulting in reduced growth and with increasing mortality, periods of carbon emissions. A typical PNW forest will be increasing carbon stores at the rate of nearly 4 mtC/h/yr through prime growth years with about 80 mtC/h stock average across all ages in a commercial rotation (Fig. 10.2). As the forest reaches its carrying capacity, growth declines to as little as 0 ± 0.5 mtC/h/yr by 150 years as the stock of carbon reaches 250 mtC/h, more than twice the average for a commercial rotation. Natural variability is high across forest stands as some max out with twice the carbon carrying capacity as others. Not harvesting provides a one-time option to store more carbon in the forest than under a commercial rotation.

Alternatively by harvesting the forest before the growth slows down if the carbon is stored in products the carbon pool will increase year after year through

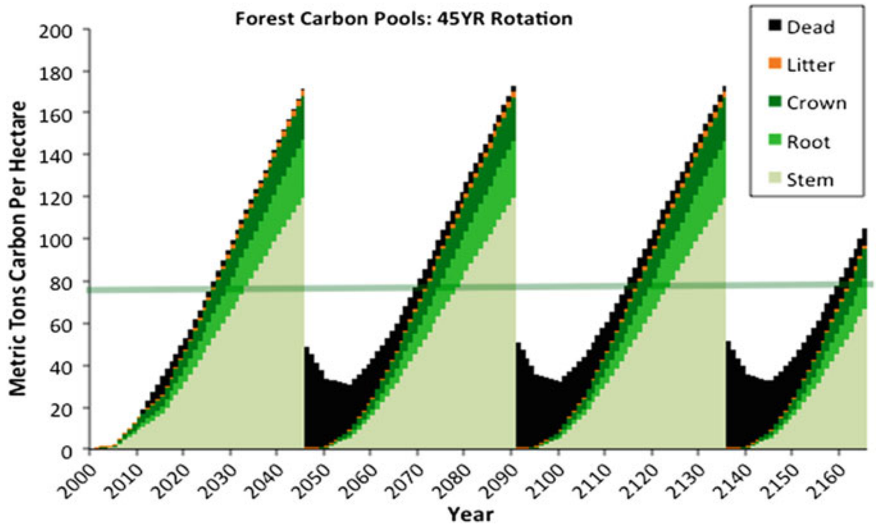

Fig. 10.2 Forest carbon pools for sustainably managed forests in the PNW using 45 year rotations (*Source* CORRIM Fact Sheet 5 (2009) http://www.corrim.org/pubs/factsheets/fs_05.pdf)

sustainable forest management where the amount of volume and carbon removed from the forest each year is set to be no greater than net growth. The forest carbon remains neutral while the carbon from product uses continues to grow sustainably, unconstrained by the maximum carrying capacity of the land. While there will be emissions from the energy required to process products, these are much smaller than the carbon being stored. In the forest there will be dead wood left behind after harvest that will be decomposing but such emissions are offset by new growth across the forest. While any given sustainably managed forest stand will experience a carbon cycle with a decline in forest carbon after harvest and an increase until the next harvest, averaged over time for a single stand or across all stands at any point in time, the forest carbon remains neutral with net new growth offset by removals and decay. While there is substantial variation in forest types across different regions requiring caution when inferring generalizations, the measurement and accounting methods illustrated here for the Pacific Northwest (PNW) are generally transferrable at least across non-tropical forests (Zobrist et al. 2005).

Under life cycle accounting (Fig. 10.3), the carbon exported from the forest into products transfers the carbon to a products pool that will be reduced by any emissions resulting from the energy needed in processing. Note that the emissions from processing (shown as a negative pool) are much smaller than from product storage and the emissions from forest management and harvesting are almost negligible by comparison.

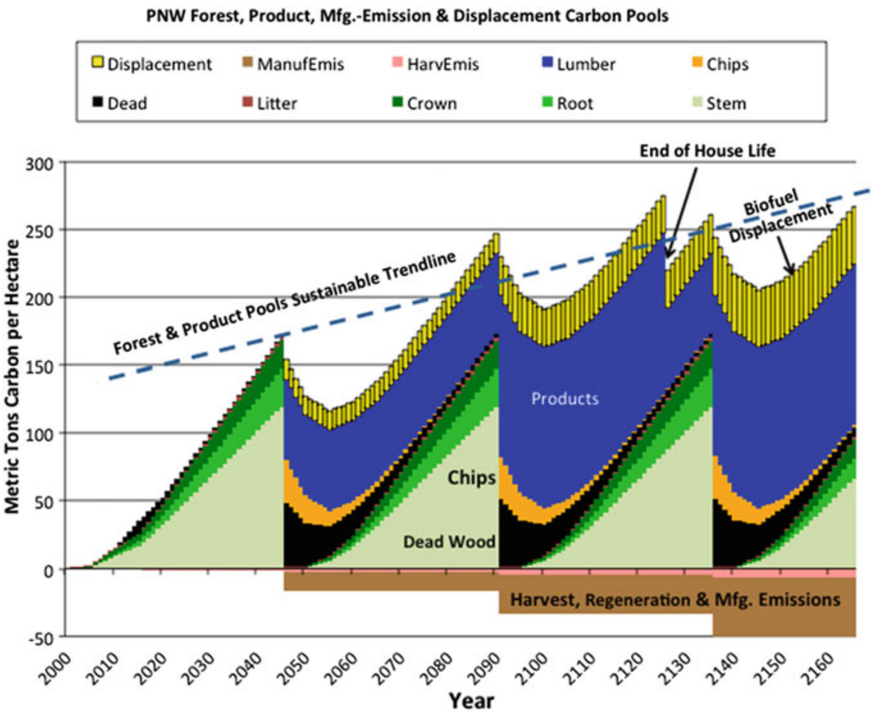

Fig. 10.3 Forest, plus product carbon pools, energy emissions and displacement carbon pools for a PNW forest (*Source* http://www.corrim.org/pubs/factsheets/fs_05.pdf and Lippke et al. 2010. Wood and Fiber Science 42 CORRIM Special Issue Fig. 5, p. 10)

In addition to the forest carbon pools, Fig. 10.3 shows the fate of the harvested products according to LCI data for the US PNW along with the total harvesting and manufacturing emissions needed to produce them (Perez-Garcia et al. 2005b). Most of the material becomes long-lived wood products largely related to housing (Winistorfer et al. 2005) or similar light construction commercial buildings that have a useful life estimated at 80 years based on historic housing data. Other products have shorter lives or may be used as a biofuel to offset fossil fuel use. The emissions from management, harvesting, log transport and wood processing reduce the pre-harvest carbon storage by about 8 % (negative carbon pool shown below the zero line). Approximately half of these emissions are offset by using internally generated mill residuals such as bark, sawdust and trim as biofuel, displacing the need for fossil energy sources such as natural gas for drying (shown at the top of the graph). Some higher grades of mill residuals or low-grade logs are used for chips and composite panel products. Short-lived products (such as chips for pulp and paper) are assumed to decompose within the rotation. The lifespan for housing is illustrated by the decline in long-lived product carbon after 80 years. End of product life assumes incineration without energy recovery, recycling or landfill, a tutorially useful but conservative estimate given the amount of wood recycling and landfilling that is currently occurring. Introducing a probability distribution for the expected life of a house merely smooths through the decline shown as the end of useful product life. An estimated 50 % of the wood waste in landfills may remain in perpetuity (Skog et al. 2008) however oxygen constrained methane emissions from the landfill may also offset much of the carbon stored in the landfill as methane is a potent GHG as justification for using conservative estimates without landfill carbon stores.

While the forest carbon remains stable as the new growth offsets the volume of removals used for products and biofuel, the carbon stored in products and the displacement of fossil fuels produces a net reduction of atmospheric carbon not long after harvest, growing with each rotation. The one-way-flow of fossil fuel emissions into the atmosphere is reduced by using a sustainably managed carbon neutral forest resource to produce bio-based products and energy.

10.3.2 Carbon Pools for Different Alternatives to Wood Products

Figure 10.3 does not show what occurs when wood is not used. For every use of wood there are substitutes and every different product use results in a different life cycle carbon footprint impact (Perez-Garcia et al. 2005a; Gustavsson and Sathre 2006; Gustavvson et al. 2006). For example, kiln dried (KD) lumber studs can be replaced by steel studs, green wood studs or concrete block walls. While a green stud or one dried using biofuels produces less processing emissions, the carbon stored in the product dominates. The lumber stud stores as much carbon even after offsetting the emissions from processing it as the steel stud emits (Fig. 10.4). While the concrete block wall emits almost twice as much as just the steel stud, a wood framed wall using a lumber stud, oriented strand board (OSB) sheathing and vinyl cladding still results in a net carbon store. Substituting wood for steel or concrete walls results in nearly 12 t reduction in emissions for either case i.e. a reduction in steel emissions of 6 t plus 6 t stored in the wood product or a reduction in the concrete emissions of 10 t plus the 2 t stored in a wood framed wall structure net of the emissions using a vinyl cladding including processing emissions (Fig. 10.4).

While there are an infinite number of substitution alternatives, a survey of available substitution studies (Sathre and O'Connor 2009) produced an average value for wood substitution of 3.67 t of CO_2 reduction for every tonne of wood used to displace other structural materials. The life cycle information collected in current wood processing mills suggests a reduction of about 1.2 t of CO_2 from natural gas for every 1.0 t of wood biofuel used, a much lower leverage of substituting wood for energy than when used to substitute for fossil intensive products. However for the lower grades of wood waste, using wood as a biofuel still displaces the emissions from the use of fossil fuels.

Figure 10.5 provides the complete tracking of carbon from the forest to products net of processing emissions plus the emission reductions achieved when wood

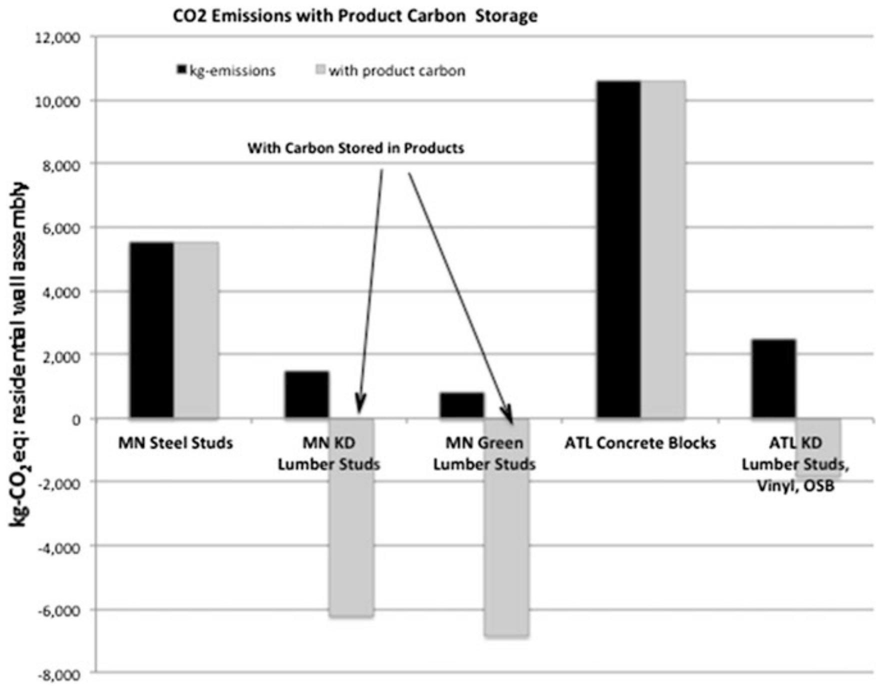

Fig. 10.4 Wood product substitution impact on carbon emissions (*Source* Lippke et al. Wood Fiber Sci, Volume 42, March 2010: Fig. 7, p. 10). *MN* Minneapolis, *ATL* Atlanta

substitutes for fossil intensive materials using the specific example of a wood framed wall vs concrete framing, a most prevalent form of substitution in US markets (Lippke et al. 2004). Carbon stored in landfills was omitted in order to assure a conservative estimate given the high variability in landfill emissions. The total carbon stored by the uses of wood from a sustainably managed stand continues to grow at about 4.7 t C/h/y more than offsetting any short term loss from the decay of dead wood left behind after harvest.

10.3.3 Carbon Pools when Forest Wastes as Well as Mill Wastes are Used as Biofuel

While using wood as a biofuel results in permanent substitution much like products substituting for fossil intensive products, the carbon mitigation leverage is much lower and the carbon in the fuel product is not stored but returned to the atmosphere. Nevertheless, by using potential biomass removals not needed for their nutrient value or for ecosystem values as biofuel to replace coal, the fact that the process is sustainable will ultimately displace more carbon emissions than can

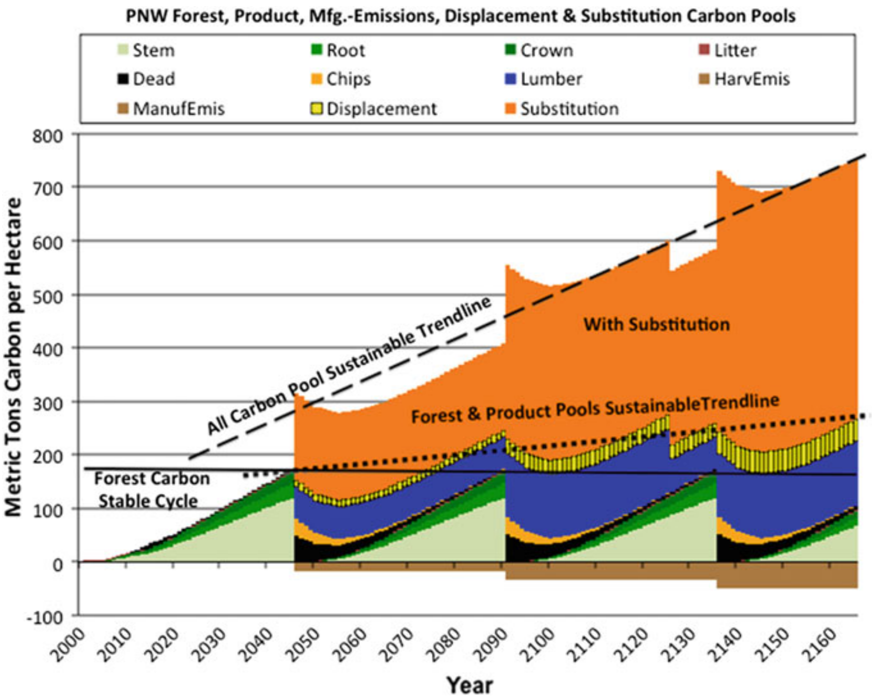

Fig. 10.5 All carbon pools: forest, product, emissions, displacement and substitution (*Source* http://www.corrim.org/pubs/factsheets/fs_05.pdf and Lippke et al. 2010. Wood and Fiber Science 42 CORRIM Special Issue Fig. 6, p. 12)

be stored in the forest, which reaches carrying capacity limits after 100 years. However as shown in Fig. 10.6, when starting from bare ground it may take more than 2 rotations before the displaced emissions exceed the maximum growth in forest carbon. While the processing emissions associated with collection of the biofuels will likely be somewhat larger than for merchantable logs, as barely visible in the figure they are relatively small and inconsequential.

10.3.4 Forest Residual Biofuel Availability

The more effective role for woody biomass as biofuel is to use the potentially collectable forest residual wastes which can be quite significant. The current use of wood mill residuals to augment use of fossil fuel energy falls short of the total mill processing energy needed because other uses of wood residuals are of higher economic value while also substituting for fossil-intensive product alternatives.

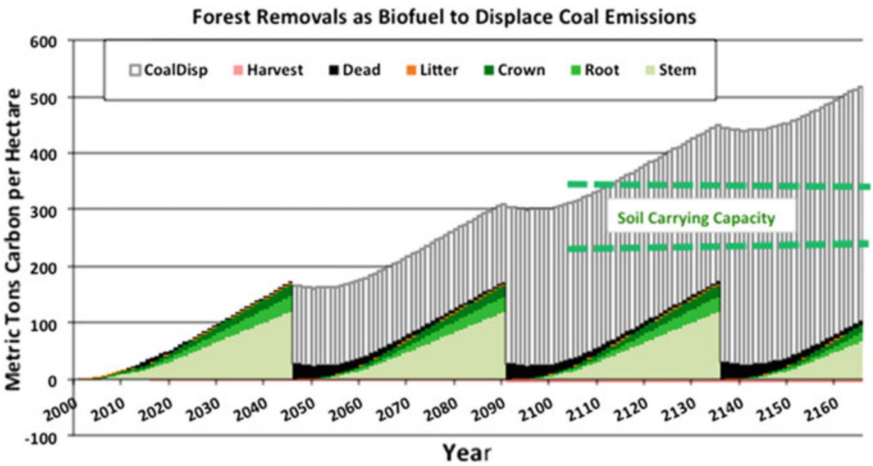

Fig. 10.6 Carbon emission reductions from burning wood as a biofuel to displace coal emissions

For a typical PNW sawmill only half of the energy needed, mostly for wood drying, is provided by mill process residuals, such as bark and sawdust which represent 12 % of total log input (6 % of above ground biomass). When forest residuals, which are currently burned or left to decay in the forest, can be economically retrieved and delivered to mill sites or other heat and power producers, additional energy can be produced to further reduce fossil energy reliance (Mason et al. 2009).

A recent study in Eastern Washington measured almost 2000 piles of forest residuals and delivered a subset of them to an electric power plant (Oneil and Lippke 2009). While half of the above ground wood was delivered to product mills for merchandising, of the remainder about 30 % was considered uncollectable leaving 35 % of the total above ground biomass as accessible. As some biomass is considered potentially important for nutrients and other values a further reduction in potentially removable waste was applied based on ecological data for the region. The net recoverable forest residual biomass was estimated to be almost 24 % of the total above ground biomass. If it were recovered, this volume is almost 4 times greater than the total biomass currently used in the wood product mills to produce energy. It is also much more than is needed for mill processing energy, which could result in a substantial flow of carbon neutral biofuel to displace coal emissions. As such it represents a substantial opportunity to reduce emissions if the cost of collection merits the effort as might be expected with increasing carbon values. It could increase the total carbon stores and offsets shown in Fig. 10.4 by 40 % relative to the carbon stored in the forest and products and 12 % relative to the total carbon stored and emission reductions with substitution.

10.3.5 Best Practices for Carbon Mitigation

Life Cycle Carbon Tracking demonstrates clearly that growing sustainable forests faster produces more carbon mitigation across all carbon pools than by avoiding harvest altogether. By harvesting the quality wood before the growth rate declines we can displace fossil intensive products as soon as possible. We can also collect the residual biomass for use as a biofuel to displace fossil fuel emissions with the caveat that biofuel collection is constrained by economics and the need to sustain nutrient requirements and ecosystem function.

Best practices will likely include fertilization where there are nutrient deficiencies, which can increase both above ground forest productivity and soil carbon stores (Adams et al. 2005). Best practices will also likely include vegetation control at the time of planting to accelerate growth and shorten the rotation making it possible to use wood to displace fossil intensive materials sooner (Briggs and Trobaugh 2001; Talbert and Marshall 2005). These practices will however alter stand structures affecting suitable habitat (Lippke et al. 2007a) and perhaps most importantly to the degree that existing but unmanaged forestland might become diverted to these prescriptions for their carbon benefits, old forest habitat (OFH) that is already considered to be in short supply may decline further.

Incentives can be effective in altering forest growth, collection of forest residuals and protection of other non-market values of particular interest. But as noted in the introduction, incentives are frequently counterproductive such that understanding why and how to avoid such consequences are important.

10.4 Productive and Counterproductive Carbon Incentives

Life cycle carbon tracking allows one to quantify the impact of carbon over all pools. It provides the opportunity to analyze the impact of changed assumptions or policies such as incentives. Before trying to generalize how to avoid counterproductive incentives it is easiest to simply analyze the impact of some of the many incentives that have been proposed and note how the incentive would likely alter the carbon from one stage of processing to the next. While there are many details and caveats in carbon contracts, a fairly simplified version is usually sufficient to characterize dominant impacts.

10.4.1 Incentives for Management of Forests Over Longer Rotations

Carbon banking frequently will pay for increasing the carbon in the forest by not harvesting. At least until forest stands reach their carrying capacity carbon in the forest will be increasing as measured by forest inventory methods or calibrated growth models. But not harvesting also shorts the flow of carbon into product stores and results in increased use of fossil intensive substitutes. The result across all carbon pools as evident from the examples provided earlier will be increased GHG emissions, a counterproductive result. Even if the removed wood is only being used for its fuel value to displace fossil fuel emissions, so long as the forest is being managed for sustainable removals producing a sustainable displacement of fossil emissions the reduction in emissions will ultimately exceed the growth of carbon in the forest, which inevitably declines as the forest ages. As this example demonstrates, incentivizing increased carbon on any single carbon pool can have unintended impacts on total carbon. Life cycle carbon accounting provides a method to analyze the impact of carbon incentives on all carbon pools. Life cycle accounting of some non-market benefits that may be in jeopardy can also be important.

10.4.2 Incentives to Increase the Use of Biobased Fuels

Corn or cellulosic ethanol tax credits will lower the cost for producing ethanol, which will in most cases displace more fossil fuel emissions than needed in production. It will also raise the price a producer will be willing to pay for the biomass feedstock, in effect diverting that feedstock away from the production of composite panels or other products that are almost certainly substituting for and displacing more fossil intensive products like wallboard or vinyl than the emission displacement from use as a biofuel, hence producing a counterproductive result. There may be ways to restrict how the incentive is used to avoid stealing other feedstock such as restricting it to currently unused sources of biomass to avoid unintended consequences.

10.4.3 Incentives to Increase the Collection of Currently Unused Forest Residuals

Incentives that reduce the cost of collecting biofuels for any end use would increase the amount of biofuel available, at least for the portion that becomes better than economic break even, and hence contribute to offsetting fossil fuel emissions whether used as a biofuel or for other composite products. But just how does one determine what is currently being collected and avoid compensation for material that would be collected anyway? And over time, how does one know what would otherwise be uncollected without the incentive? Markets will change and as the value of carbon increases the determination of what is not collectable becomes problematic.

10.4.4 Mandates Requiring Utilities to Use Not-Less-Than a Minimum Percentage of Biofuel in Their Feedstock

Worse than incentives to collect unused forest residuals, minimum standards to consume renewable fuels effectively requires the energy producer to pay whatever it takes, i.e. to outbid any other user to gain access to the required amount of biomass. Such a requirement is not even dependent upon cost except perhaps through the payment of penalties for failing to meet the requirement. It not only steals the feedstock of other users that will likely have higher leverage in lowering emissions, it fragments the supply base making it more difficult to invest in scale processing such as cellulosic ethanol production.

10.4.5 Incentives to Substitute for the Most Fossil Intensive Products

Incentives to increase the supply of low valued end products as described above will inevitably steal feedstock from better uses. Each of the above examples fails by trying to provide a small incentive to increase carbon stores or offsets without considering the alternative use of the material even if only by the inability to measure it. But if we incentivize reducing the use of products that produce the most emissions, in this case stealing the feedstock from other uses that are currently producing less of a reduction in emissions, there will be a productive change. Incentives that increase the cost of every product proportional to its carbon emission intensity will motivate the efficient use of every grade of wood fiber where it can have the greatest impact. A fossil carbon pollution tax levied on the carbon extracted from deep pools would pass the costs of carbon emissions through the market without the need for complex trading rules covering every stage of processing and result in increased use of wood where it will contribute the greatest reduction in emissions.

10.4.6 Incentives to Build Structures that Use the Least Amount of Fossil Emission Intensive Products

While not equivalent to the efficiency of a carbon tax any incentive directed at the highest leverage uses of wood to reduce emissions such as replacing steel and concrete where wood can be used will most likely steal the feedstock from less effective alternatives and may even steal feedstock such as biofuel raising the potential of the feedstock to reduce emissions more than just displacing the energy equivalent in fossil energy emissions.

10.4.7 Summary of Avoiding Counterproductive Incentives

Incentives vary and can be directed in many different ways. When directed at the lowest leveraged uses such as producing biofuel to substitute for fossil fuel, currently collected feedstock will likely be diverted away from current uses that are contributing more to carbon mitigation than biofuel, a counterproductive impact. When incentives are directed at the highest leveraged uses, lower valued feedstock currently contributing less to carbon mitigation will likely be diverted to more effective uses. *Incentives that can increase the cost of every product proportional to its carbon emission intensity will motivate the efficient use of every grade of wood fiber where it can contribute the greatest reduction in carbon emissions.* While this may have the appearances of a tax to the consumer, it should be considered a pollution fee with tax offsets adjusted so that the fee is income neutral thereby incentivizing carbon mitigation with minimal implications on income supported economic activity.

10.5 Ecosystem Impacts of Carbon Policies

Prior to concerns about the negative impacts of global warming, carbon was valued in the market positively as a source of energy, which is traded in the market with the price determined by the cost of production relative to the value gained by purchasers. Markets facilitate the buying and selling of goods and services at market-established prices rising when the value to purchasers exceeds the cost of production and falling when there is more supply than price sensitive purchasers want.

10.5.1 What Do Markets Pay For?

Purchased goods from forests include timber and fiber used for wood products, as well as paper and biofuel energy products. Additionally, there are other non-timber products derived from the forest that may be used for commercial purposes. Some costs are incurred that are internalized in the market price as a result of implementing environmental laws and regulations. This is often in the form of insurance to reduce the risk of damage as a result of litigation in courts or additional staffing with relevant expertise that a company or land manager takes on to reduce the risk of negative impacts on surrounding neighbors.

Prior to the development of carbon markets to reduce carbon emissions, products made of wood provided un-priced benefits over substitute products like steel studs or concrete walls used in building construction as they resulted in lower emission burdens than alternative products over their life-cycles. Similarly prices generally do not include the value of the numerous benefits forests contribute to clean air and water, habitat protection and biodiversity, recreation and aesthetics although there are many ongoing efforts to create value for some ecosystem services. Many ecosystem service benefits are still provided free of charge to those who benefit from them even as the impact of regulations directed at some benefits results in higher production costs, which are absorbed into management decisions without a market price mechanism to determine if the benefit justified the cost or who paid for the benefits.

As the value of carbon rises, it will affect many of these currently un-priced non-market benefits. Best practices for reducing carbon mitigation motivate faster forest growth to produce carbon emission free products. While habitat suitability for a range of species is driven by stand structure attributes, carbon impacts are characterized by the volume of production and quality of wood produced, rather than the diversity of forest structure. For habitat protection it becomes important to understand not only the life cycle of carbon but also the life cycle of forest stand structures and its impact on habitat suitability. While tracking carbon was shown to require a life cycle analysis of impacts across each impacted carbon pool, habitat suitability and protection requires a life cycle analysis of those forest structures that contribute to habitat suitability. Species that prefer dense forests are likely to benefit from management focused on increasing carbon mitigation while species that prefer the complex structures in older forests are likely to experience reductions in suitable habitat unless the values of habitat can also be internalized into the market.

10.5.2 Forest Structure Based Life Cycle Analysis

Early work on structure based management to maintain biodiversity split stands into just a few classes such as an initiation stage following regeneration, a dense structure phase once the canopy had closed, a beginning diversity stage with the onset of greater mortality, and ultimately a complex Old Growth stage, while also recognizing Savannah like structures that evolved from frequent understory clearing fires (Oliver and Larson 1996). This course filter approach was useful in characterizing habitat sensitive to one of these broad categories. Species-specific habitat modeling requires many more structure classes. Johnson and O'Neil (2001) developed habitat suitability measures for a large number of species by characterizing the life cycle of stand structures for 38 structure classes. This provided considerably more detail than the earliest course filter approaches providing a matrix of habitat suitability for many different species.

One observation from using their structure classes was that given the increased supply of forests managed for commercial purposes on short rotations, those species that preferred dense structures as well as those that like substantial openings could find suitable habitat within commercially managed forests. Conversely, habitat for species that preferred older forest structures with greater complexity was in short supply, with substantially less habitat than earlier in the century such as for the Pileated Woodpecker and Douglas Squirrel.

Structure based management can be used with more rigorous statistical methods than the Johnson and O'Neil structure classes to assess whether a given stand condition is similar to or different than target habitat conditions such as the conditions in the immediate vicinity of Northern Spotted Owl nests. Since owl habitat has been largely identified with old forests, the assessment can be used to test whether a management pathway is effective at producing old forest conditions over time (Gehringer 2006). The assessment procedure provides a robust statistical approach for assessing whether any given management pathway can achieve any future target forest condition that can be identified by a group of stands. We illustrate use of such an assessment to select best management pathways across the forests life cycle to restore old forest habitat (OFH) conditions while also evaluating the impact on carbon.

10.5.3 Carbon as a Competitor Rather than Complement to Old Forest Habitat

For demonstration we concentrate on the protection of Old Forest Habitat (OFH) as the non-market value in shortest supply given the importance of longer than commercial rotations and retention of large trees that result in a higher opportunity cost to produce OFH than needed for other species or forest values. We determine the opportunity cost of producing habitat by determining the lost revenue to achieve habitat objectives relative to commercial management with and without carbon values included as revenue. By simulating the life cycle carbon impacts for a range of forest treatments while using a forest structure-based metric for old forest habitat suitability, we can determine what it costs (revenue lost) to increase OFH. We use a statistical test for the suitability of habitat by measuring the percentage of time that the treated stands are not statistically different than a sample of old forests that were also observed to span the range of conditions where northern spotted owl nests were present (Gehringer 2006; Lippke et al. 2007b). The primary parameters used in the statistical test to determine when a treated stand is not significantly different than a sample of old forests are trees per acre (or hectare, TPA or TPH—a measure of density), quadratic mean diameter (QMD—a measure of tree size), canopy closure, and canopy layering, requiring a life cycle examination of these parameters much the same as life cycle carbon accounting. Customized thinning treatments for different initial density conditions (low, medium, and high) are selected based on the best performance metric for moving stands at the time of initial thinning to most quickly and at least cost take on the statistical properties of old forests (solid gray dots in Fig. 10.7 with northern spotted owl nests identified as the black dots within the area) (Lippke et al. 2007b).

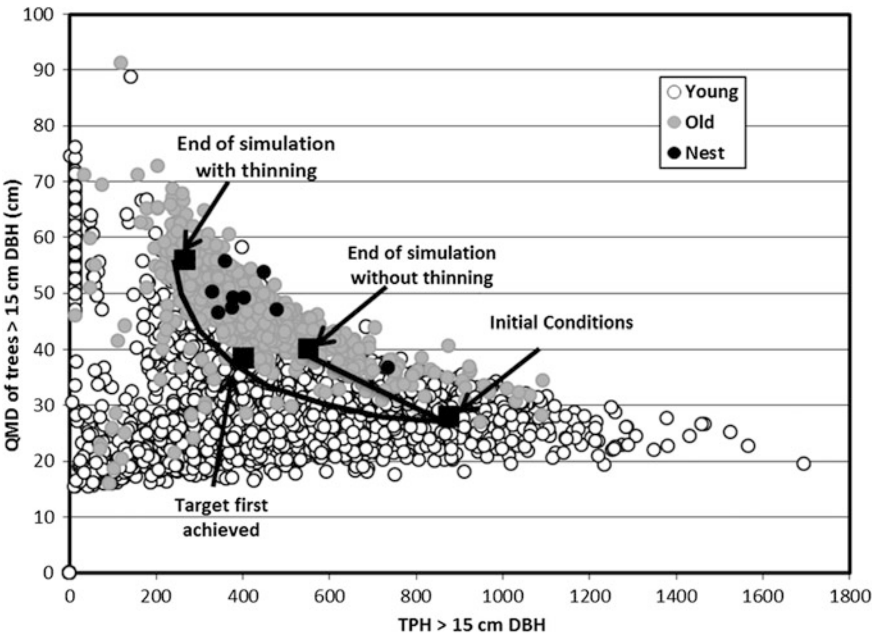

Fig. 10.7 The QMD and TPH trajectory to reach old forest and owl nest conditions by thinning. (*Source* Lippke et al. 2007b)

Figure 10.7 shows that the trajectory from a high density stand without thinning barely reaches the edge of the old forest target conditions while the thinned stand reaches target conditions much sooner progressing to the center of the target in the middle of the conditions supporting owl nests in the same length of time.

The present value (PV) of the revenue loss to the landowner from thinning treatments to reach OFH (using an inflation adjusted 5 % discount rate for the time value of money) provides a measure of the incentive that could make the landowner equally likely to produce habitat vs strictly commercial production. These procedures are generalizable across regions (Zobrist et al. 2005) although the treatments must be customized to initial forest structure conditions and projections are dependent upon the calibration of the growth model, in particular to include mortality implications on structure.

Table 10.1 compares the treatment impact differences across four alternatives, (A) the 45 year commercial rotation as the highest revenue producer for a baseline, (B) a biodiversity pathway involving one or two wildlife thinning treatments before a 100 year rotation clearcut, (C) a long rotation with a clearcut and regeneration at 100 years, and (D) a no harvest alternative.

Biodiversity management involving custom designed successive thinnings to produce OFH has been shown to be the lowest cost method of producing/maintaining OFH (Carey et al. 1999). We use an un-weighted average of the percent time the treated stand is not statistically different than OFH over the first 100 year

Table 10.1 Treatment impacts on PV of merchantable timber, forest carbon, total carbon, and all values—initiated at forest regeneration

Treatment	PV Timber Market PV$/h	Market Loss (Cost) PV$/h loss	PV Forest Carbon PV$/h	PV Timber & Forest C. PV$/h	PV Total Carbon PV$/h	PV Timber & Total C. PV$/h	Opportunity Cost M&TC PV$/h loss	% Time in OFH %	Merch $/ % in OFH $/%	Total $/ % in OFH $/%
A: 45 yr Rot	4,254	base	4,708	8,962	6,581	10,835	base	0	base	base
B: Bio-pathway	1,767	2,487	4,856	6,623	5,711	7,478	3,357	34.8	71	96
C: 100 yr Rot	523	3,731	4,288	4,811	4,480	5,003	5,832	13.9	268	420
D: No Harvest	0	4,254	0	0	4,257	4,257	6,578	13.9	306	473

life of the forest derived from best selected treatments over a wide range of initial stand conditions although the simulation demonstration is only for a single representative stand (mid site, high density in Lippke et al. 2007b). We initiate the present value computations from bare land as the beginning of the life cycle thereby measuring the expected value of the revenue that can be produced from the soil independent of any initial stand inventory. While management costs will have some impact our focus can be narrowed to the impact on revenue, which dominates policy considerations.

The PV of a merchantable timber market of $4,254/h for a 45 year rotation is comparable to the PV of the forest carbon value of $4,708/h based on a carbon value of $25/mt CO_2 ($92/mt C or $46/mt dry wood with annual payments of $248/h/y from 2.7 mt C growth/yr over the commercial rotation). While this is within the current ECX carbon price trading range, carbon prices can be expected to increase further in order to meet carbon mitigation objectives (Nordhaus 2001). When product carbon stores and product substitution displacement of fossil intensive product emissions are included such as illustrated in Fig. 10.5 while using this same value for carbon, the total PV of $10,835/h is more than twice the merchantable timber value.

To evaluate the impact on critical habitat as the biodiversity metric at greatest risk, we select a best biodiversity management pathway customized to stand conditions at the time of thinning, which produces stands not statistically different than OFH sample stands 35 % of the time in the first 100 years. The opportunity cost to produce those OFH stands is $2,487/h based on the timber market revenue loss, or $3,357/h including carbon values, a 35 % increase in cost due to the value of carbon. While the Bio-pathway treatment was selected as among the most efficient, the opportunity cost per 1.0 % OFH increases from $71/% OFH to $96/% OFH when carbon values are included. Producing OFH is competitive with carbon management, not a complement. Long rotations increase forest carbon but reduce carbon mitigation with less carbon stored in products and less reduction of fossil emissions from the substitution of non-wood products such as steel and concrete.

A long rotation set at 100 years is 4 times more costly in producing OFH than the Bio-pathway and the No-Harvest alternative almost 5 times more costly. The value of the carbon in the forest is insignificantly different across the four

Table 10.2 Treatment impacts on PV of merchantable timber, forest carbon, total carbon, and all values—initiated at harvest

Treatment	PV Timber Market PV$/h	Market Loss (Cost) PV$/h loss	PV Forest Carbon PV$/h	PV Timber & Forest C. PV$/h	PV Total Carbon PV$/h	PV Timber & Total C. PV$/h	Opportunity Cost M&TC PV$/h loss	% time in OFH %	Merch $/ % in OFH $/%	Total $/ % in OFH $/%
A: 45 yr Rot	38,652	base	4,708	43,360	23,204	61,856	base	0	base	base
B: Bio-pathway	15,898	22,754	3,696	19,594	11,379	27,277	34,579	34.8	654	994
C: 100 yr Rot	4,736	33,916	4,288	9,024	6,561	11,297	50,559	13.9	2,440	3,637
D: No Harvest	0	38,652	3,832	3,832	3,832	3,832	58,024	13.9	2,781	4,174

treatments as each scenario starts from bare land with the same forest growth profile during the early years. The discount rate reduces the value of carbon produced in the longer term. The discount rate also reduces the value of product carbon because it is produced at the end of a rotation whereas the forest carbon accumulates steadily over time until reaching the lands carrying capacity. Note that a discount rate applies only to monetary values not the physical volume of carbon. Under scenarios with rising carbon values over time the Present Value of product carbon will be substantially higher than shown.

Since sustainable management of a forest requires a base investment in the forest, sometimes referred to as a sunk cost, management decisions are more likely to be impacted by immediate decision choices such as whether to cut, thin or delay, rather than looking at the long term productivity that can be achieved from the bare land. As an alternative to starting with bare land we initiate the life cycle analysis with the harvest of a mature stand (age 45) which for commercial rotations would then be sustained with periodic rotations (Table 10.2).

The market PV resulting from initiating the revenue accumulations on the initial harvest (Table 10.2) is $38,652 compared to a forest carbon value of $4,708 a total carbon value of $23,204 with a total for all values of $61,856. The forest value is unchanged by starting with merchantable stands whereas the market and product carbon values are much higher as they are event driven 45 years earlier including the value of the maturing forest, not just the value of bare land as characterized in Table 10.2. The decisions on the future path of management will depend heavily on current market conditions and expectations regardless of the decisions that motivated the establishment of the commercially mature forest structure. The increased cost to reach OFH is largely the cost of reaching the 35 % time in OFH 45 years earlier. It costs much less to start from bare land than to start with a mature stand which has a timber value of over $30,000/h.

The merchantable timber opportunity cost to achieve OFH with the Bio-pathway is $22,754/h or $34,579 for both merchantable timber and total carbon values. Higher values for carbon are not complementary to the production of OFH as the cost (revenue loss) increased by 52 % or $11,825/h with the addition of carbon values as the incentive needed to make a land manager indifferent between a commercial rotation and a biodiversity pathway. Since the Bio-pathway produced

OFH 35 % of the time, the opportunity cost per 1 % increase in time spent in OFH increased from $654/% OFH/h for merchantable values to $994 for total timber and carbon values. The longer rotation without the biodiversity thinning was 4 times less efficient compounded by reaching OFH conditions only 14 % of the time while the timber values and carbon values were substantially reduced as well.

10.5.4 Summary of Carbon Valuation Impacts on the Opportunity Cost to Produce Critical Habitat

As carbon values increase, so does the opportunity cost of producing old forest habitat as the most costly habitat to protect. While the current base of sustainably managed acres are largely commercial and rarely being managed to produce OFH, the opportunity to incentivize such production will become even more costly as carbon values increase. The opportunity cost of maintaining acres in OFH that are currently not being harvested or those on long rotations (case C and D which are typically practiced on public lands) is far from optimum for the production of OFH.

It is unlikely that other non-market values are at as high a risk as OFH to disturbances given the increasing risk of hazardous fires from climate change and the high fire risk conditions resulting from a history of fire suppression (Oneil and Lippke 2010). The natural events that produced OFH stand conditions historically are being substantially altered by climate change and other anthropogenic impacts on the forest. Given the substantial change in forest structure for dry interior stands resulting from a century of fire suppression, thinning stands may result in reduced fires and carbon emissions as well as restoration of historic stand structures and habitat. In this case carbon mitigation and restoration of historic habitat can be complements for a win/win treatment strategy if the non-market values were internalized into the decision process.

Just as the life cycle analysis of carbon impacts is critical to understanding the impact across all carbon pools, a life cycle analysis of forest structures is critical to understanding the impact on habitat. As shown by the order of magnitude increase in opportunity cost when initiating treatments with near term impacts in contrast to decisions made at the time of regeneration it will be much less costly to incentivize habitat production over the long run than to require short term results. Efforts that attempt to claim joint benefits for protection of habitat at the same time as increasing forest carbon through long rotations generally fail to consider life cycle accounting. The implicit value of existing OFH is high and will be made higher as carbon values increase although there may be regions where habitat restoration benefits from treatments.

Regulatory actions to produce and protect OFH rather than compensatory incentives will impose high costs on those affected and likely motivate land conversions that are counterproductive to maintaining non-market forest values.

10.6 Avoiding the Non-Market Costs of Fires

Fighting forest fires can be quite expensive and poses a threat to human life, wildlife and habitat. Fires also release large pulses of GHGs potentially converting forests from carbon stores to emission sources. Forest fires are increasing (McKenzie et al. 2004). The risk of fire and cost of fighting fires can be reduced by management treatments (Agee and Skinner 2005). Although forest owners incur the cost of such treatments, the general public is the greatest beneficiary. This type of avoidable cost does not benefit the forest owner and therefore is still considered a non-market benefit.

It is estimated that for the period of 1999 through 2002, the average cost of fire fighting for the Washington State Department of Natural Resources (DNR 2004) was approximately $2,000 per acre ($4,940/h); for the federal government, the cost was $1,172 per acre ($2,895/h). Removal of small diameter trees to reduce hazardous fuel conditions is known to be costly. Large trees can be removed for their lumber and other product values as reflected in the market; however, the market value for smaller logs is often less than the harvest and hauling charges. As a trade-off, failure to remove small diameter trees results in the retention of fuels that support the transfer of a ground fire to an unnatural and more devastating crown fire. For this reason risks of severe wildfire impacts are far higher on federal forests as they are largely unmanaged except for fire suppression, which results in overly dense stands that are more prone to devastating crown fires. Fires supported by overly dense stands and ladder fuels result in carbon emission increases, lost habitat and reduced soil productivity, in contrast to sustainable management for multiple uses (Bonnicksen 2008; Bormann et al. 2008). If the negative impacts that result from crown fires were fully reflected in the market, there would be much higher motivation to avoid them, providing the necessary incentive to remove high fuel loads compensating for the cost.

Land management decisions aimed at reducing the risk of fire can have a high benefit to cost ratio when all market and non-market costs and benefits are included. Firstly, the cost of fighting fire could and should be considered a cost of not removing high fuel loads. The estimates provided by Mason et al. (2003 and 2006) for the present value of the cost associated with risk avoidance (i.e., costs associated with fighting fires): were $1188 per hectare for a high-risk forest and $571 per hectare for a moderate-risk forest. These NPV differences arise from estimates that high-risk forests are likely to burn within 30 years whereas moderate-risk forests are likely to burn within 60 years. Avoided cost estimates can be evaluated in many ways but the range of expected costs is not large enough to justify the use of a more complex procedures.

There are many other non-market values associated with the reduction of fire risk that should be important to forest owners and to society at large. Habitats for threatened and endangered species are valued by many citizens but may be lost to wildfires. Fires reduce the carbon stored in the forest and the opportunity to produce long lasting pools of carbon stored in products. Fires prevent the use of

Table 10.3 Estimated values and avoided future cost for fire risk reduction treatments

Fire treatment benefits	Avoided-cost/hectare		Treated Okanogan
	High risk	Moderate risk	Landscape
Fire fighting costs avoided	$1,188	$571	$799
Fatalities avoided	$25	$12	$17
Facility losses avoided	$371	$178	$249
Timber losses avoided	$1,907	$916	$1,282
Regeneration and rehab costs avoided	$296	$143	$200
Community value of fire risk reduction	$156	$156	$156
Regional economic benefit	$953	$953	$953
Critical habitat	?	?	?
Smoke	?	?	?
Carbon	**?**	**?**	**?**
Water quality and quantity	?	?	?
Erosion	?	?	?
Other	?	?	?
Total benefits	**$4,896**	**$2,929**	**$3,655**
Treatment costs			
Operational costs	$924	$924	$924
Contract costs	$509	$509	$509
Environmental impact of removals	?	?	?
Total cost	$1,433	$1,433	$1,433
Net benefits of fuel removals	**$3,463**	**$1,497**	**$2,223**
Ave carbon saved (per treated hectare)			27.4 mtC/h
Lost carbon value avoided ($/h)			**$2,516**

biomass for energy conversion and green energy credits. Regeneration after fires is sometimes problematic and costs are generally very high. Post-fire rehabilitation is needed to avoid serious erosion and water contamination from excessive sediment. Surface water consumed by overly dense stands could be saved for other uses such as salmon habitat, municipal reservoirs, and irrigation. In addition, there is a financial value of avoiding facility losses and human fatalities. Communities value a lower fire risk and reduced smoke. These benefits, when aggregated by Mason et al. (2006) were estimated at $4,896 per hectare for high-risk forests and $2,929 per hectare for moderate risk forests (Table 10.3). Their estimated cost of treatment to reduce the risk of fire was $1,433 per hectare resulting in net benefits in terms of avoided future costs of $3,463/h for high risk stands and $1,744/h for low risk stands.

A positive benefit was achieved without including carbon or critical habitat values. We extended their table of benefits and costs to provide an estimate of the impact of fire reduction on the Okanogan Federal Forest as developed in Lippke et al. 2008. The net benefit for the treated Okanogan Landscape was $2,379 per treated hectare. The average carbon saved per treated hectare was 27.4 mt/C which when valued the same as earlier examples at \$25/mt CO_2 (\$92/mt C) results in avoiding the loss of carbon from fires of \$2,516, larger than the sum of all the benefits Mason et al. were able to estimate. Since the Okanogan Federal Forest treatments are limited to thinnings that retain overstory trees with relatively few removals of larger trees that would contribute more to carbon storage and substitution, fire avoidance could be coupled with even greater carbon benefits with perhaps little impact on habitat.

Under current market mechanisms, forest owners/managers are not the beneficiaries as they absorb the cost while benefits flow to other stakeholders. Therefore the initial treatment cost should be interpreted as a public investment with the discounted value of expected avoided costs as the payback. A major difference between the non-market benefits of avoiding future costs vs the value of habitat is that the avoided future costs to society can be estimated from experiential observation of recent fires and their costs, a much better estimator of the non-market values than is possible for many non-market benefits.

While it may seem unlikely that carbon values would become available in the market as the incentive to reduce fire risks, reducing fire risks are complementary to carbon and for stands with high fire risk that threaten critical habitat appear also to be complementary to habitat.

10.7 Estimates of Non-Market Forest Values

The economic analysis of the carbon and habitat life cycles provided estimates for the opportunity cost of producing increased carbon mitigation and critical habitat. Knowing the cost of production does not solve the problem of whether or not the benefits produced are greater than the costs. Many studies have demonstrated that the public is willing to pay for at least some forests managed for multiple uses in addition to timber. Xu et al. (2003) estimated the willingness of different public groups to pay for habitat and accept related consequences such as lost jobs. To be useful in policy knowing that a public has a certain value for a specific environmental attribute is still not enough to formulate policy, as one also needs to know whether a policy action can actually produce the stated benefit. Knowing the public's willingness to pay to avoid declines in an endangered species habitat may not be sufficient as endangered species populations may not respond to improving their habitat. Protection of the northern spotted owl at substantial cost, especially to affected landowners, has not altered the declining trend in the owl population implying that models of the owl's ability to survive are inadequate. Similarly improving riparian habitat for salmon may not have a sufficient impact on salmon populations given the influences of adequate food in the ocean, fishing, and migration losses associated with dams.

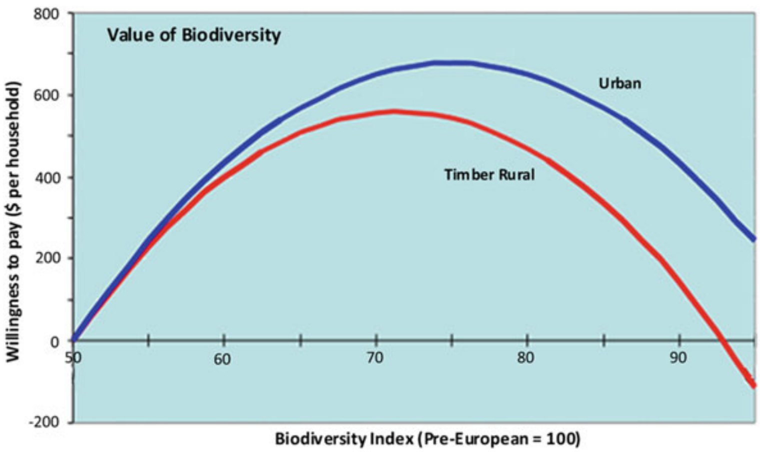

Fig. 10.8 Willingness to pay for biodiversity

10.7.1 Estimates of the Willingness to Pay for Biodiversity

Although different communities have different demands for biodiversity, both urban communities (typically far removed from forested areas) and rural communities (located adjacent to forested areas) have demonstrated significant willingness to pay for the maintenance of biodiversity. Based on the Xu el al. (2003) experimental choice survey, both urban and rural communities were willing to pay to maintain biodiversity at a level above young, commercial forest conditions (Index scale 50 on Fig. 10.8); but their willingness did not support reaching a level that would imply a return to pre-European forest conditions (Index scale 100 on Fig. 10.8). Beyond the biodiversity index 75, neither community derived any additional utility from further improvements in biodiversity. Biodiversity was characterized in the survey by pictures with varying degrees of structural complexity in forest stands as a surrogate noting the importance of such stands for species that are usually only found in old forests.

10.7.2 Estimates of the Willingness to Pay for Aesthetics

These same communities also demonstrate a WTP for improved forest aesthetics defined by the differentiation between short rotation dense forests and more mature less dense forests. When provided with images of different stand structures, respondents demonstrated a willingness to pay for forests that appeared to have older trees and more complex stand structures whether produced by mechanical thinnings or mortality from aging. Urban residents had significantly higher

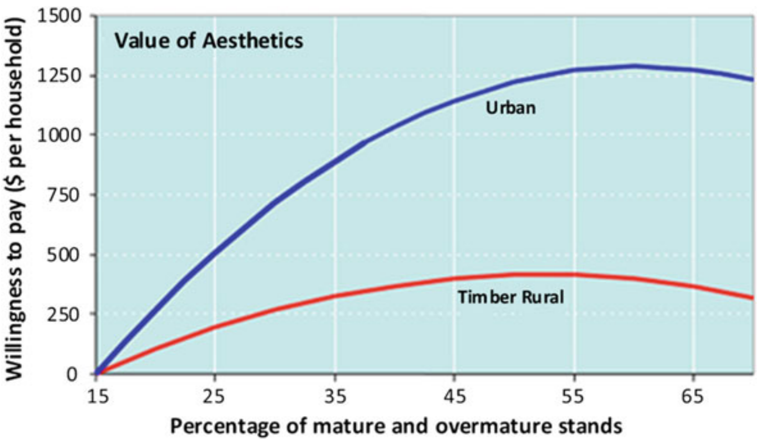

Fig. 10.9 Willingness to pay for aesthetics

willingness to pay for increases in aesthetic levels than rural timber communities (Fig. 10.9).

10.7.3 Estimates of the Willingness to Accept Job Losses

Managing forests to increase biodiversity or aesthetics is likely to reduce jobs in rural areas, which at least partially offsets the value of environmental benefits. Both rural and urban residents were similar in their willingness to accept reduced jobs in order to gain other benefits (Fig. 10.10). For $200 per household per year in other benefits, such as aesthetics and biodiversity, each group would accept a loss of 5,000 jobs, up to a level of about $1,000 in benefits for 25,000 jobs lost. Beyond that level, survey respondents valued each job less and less. Since urban incomes are twice as high as rural incomes, the rural community is willing to pay twice as much per income to save rural jobs.

10.7.4 Experimental Choice Estimates of the Value for Product and Building Standards with Lower Environmental Burdens

In recent years, growing consumer awareness of the environmental consequences of their purchases has had a demonstrated effect on the choices they make. Greater attention is also being paid to the environmental effects of building products industries. Using results from life cycle assessments (Lippke et al. 2004), a recent study analyzed household preferences for reductions in environmental emissions from building products (Robbins and Perez-Garcia 2005). In this survey,

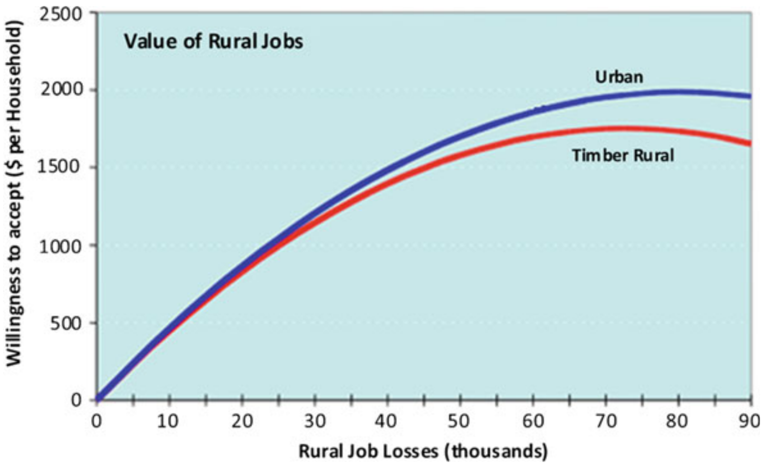

Fig. 10.10 Willingness to accept job losses

respondents were asked to assess a set of goods with different levels of emissions and price attributes and choose their most preferred alternative.

The results revealed consumer attitudes about the attributes associated with building materials used in new home construction with respect to their environmental emissions. This product attribute information has important policy implications for programs that could help achieve certain environmental standards and may lead to consumer preferences in support of building materials that produce lower environmental burdens. The results from this study suggest that consumers are sensitive to differences in the amounts and type of emissions that building materials produce.

Respondents were willing to pay for up to eleven tons of reduction of greenhouse gas emissions associated with building a new house (Fig. 10.11). Considering that a typical house produces twenty tons of such gases during the construction process, this assessment is significant. Respondents were also willing to pay for 18 % reductions in both air pollution and solid wastes.

When we combine the survey results with life cycle assessment results produced by Lippke et al. (2004), it suggests that wood-based framing construction (instead of steel- or concrete-based framing) can better achieve certain environmental standards since, particularly in the case of greenhouse gas emissions, wood framing has lower green house gas emissions than either steel- or concrete-framed houses. That is to say that the reduction in the number of tons a respondent was willing to pay for exceeded the inherent reductions when these two framing systems were compared. For example, in Minneapolis, using wood frame instead of concrete results in a 9.8 tons reduction in greenhouse gas emissions; in Atlanta, using wood instead of concrete results in a 6.6 tons reduction. As noted, respondents were willing to pay for up to 11 tons of reduction.

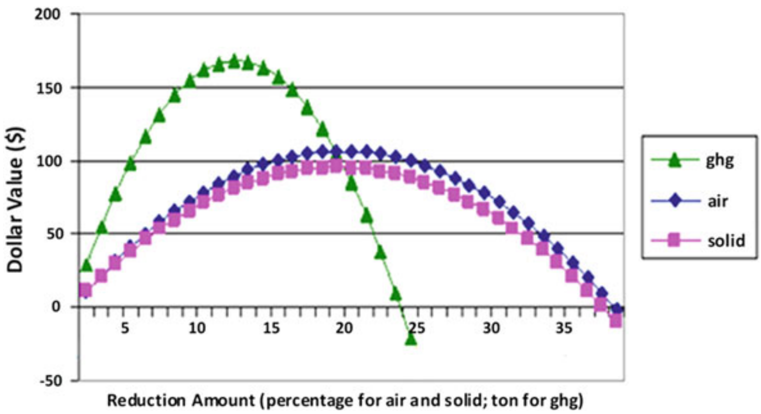

Fig. 10.11 Willingness to pay for reduced emissions and wastes in home purchase

These results, along with the steady growth in green building initiatives, indicate that consumers are sensitive to particular environmental emissions and attributes. In order to serve these consumers better, product information must be provided in order to allow them to make informed buying decisions.

10.7.5 Summary of Estimates for Non-Market Values

The values expressed above demonstrate that the public values both market and non-market benefits provided by forests, including enhanced biodiversity and forest aesthetics, as well as reduced environmental emissions through the use of "green" building products. If management decisions are targeted at more than providing traditional timber values, there are significant benefits to be received. It is important to understand the value of these benefits and to assess the level of consumer demand for them. In contrast, regulations that result in increased costs to meet environmental standards while ignoring the values provided by working forests such as clean air and water are more likely to promote land conversion than sustainable forestry. The unintended consequence of regulations is that they drive up the cost of viable forest management, demonstrating another example of the problem of not considering the importance of non-market values (Zobrist and Lippke 2007). So long as non-market criteria are mandated, and hence absorbed by producers as costs, working forests will also continue to become less competitive. This will have undesirable implications for land conversions to non-forestry uses. By contrast, creation of market-based incentives for the provision of environmental services can help keep forestry as a viable land use alternative to development.

There are however serious difficulties in valuing non-market benefits. In the examples shown, the options provided to respondents were measureable and could be related directly to actions that could be taken through policy incentives, such as changing the aesthetics based on the respondent's choice of pictures resulting from forest management treatments. The carbon options were described in terms of the impact on a residential structure without a meaningful link to whether it would meet any national or global objectives. Biodiversity was described in terms not of species populations but in terms of forest structure that provides habitat that can be changed by management treatments. Willingness to pay for some values such as fish habitat may not be useful if the link between riparian management and impact on fish populations is weak, with uncontrollable factors dominant.

10.8 Conclusions

Estimating the costs of producing non-market benefits that can be altered by forest management or product uses can be developed as an important element in a decision support framework targeted at reducing environmental burdens and improving non-market benefits. The potential future values of carbon may be very high and dominate other non-market values and even many current market values. Estimating values for some non-market benefits such as avoiding future costs by reducing the risk of fires can also be developed based on historical experience.

Basing incentives on such costs does not solve the problem of whether the benefits received exceed the cost. Estimating the consumers or societal values of many non-market benefits can provide relative information when comparing some benefits with others as support for public investments in non-market benefits but with considerable caution on whether the results are biased by the limits in testing what consumers would actually be willing to purchase given many other demands on their financial resources.

There are however many opportunities for improvement that can be identified by developing and comparing life cycle impacts for a wide range of environmental burdens and benefits. Just to account for the total carbon across all stages of processing and product uses, life cycle inventory and assessment methods are needed. Understanding the direct and indirect substitution impacts between fossil fuels and forests is essential to insure that policy decisions do not result in unintended consequences such as increasing forest carbon while failing to acknowledge reductions in product and substitution pools or diverting the use of feedstocks to alternative uses that contribute less to the displacement of fossil intensive products and their emissions. By tracking the inputs and outputs for each stage of processing, the life cycle inventory (LCI) of a product can be traced from cradle to grave, and compared to other products and processes, providing the required blueprint for life cycle carbon accounting across all carbon pools or other non-market benefits such as habitat suitability characterized by changes in stand structure.

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Part IV
Incrementalist Approaches to Forest Resource Economics

Chapter 11
Economic Modeling in Forestry: Avoiding the Lucas Critique

Karl-Gustaf Löfgren and Peichen Gong

Abstract Timber supply is a primary object of economic modeling in forestry, especially in the context of policy evaluation. Policy changes have two potential effects on timber supply. First, they may change the relationship between the quantity of timber harvested and its determinants. Secondly, they may alter the values of the factors that influence timber supply. A standard approach for policy evaluation is to estimate the supply function from observed harvest behavior, and then use the obtained supply function to simulate the effects of policy changes. A limitation of this approach, known as the Lucas Critique in economics literature, is that it usually cannot capture the first effect of policy changes on timber supply. This paper presents a new approach to estimate the timber supply function by introducing two applications in counterfactual comparisons. The approach seeks to optimize the supply function parameters under a given set of policy conditions. In the first application, we determine the change in the supply function following a change of the market regime and measure the welfare gain from competition in the timber market. The second application examines the effects of tree improvements on the timber supply function and on the producer and consumer surplus. These two cases illustrate that our approach is capable of determining the change in the supply function coefficients induced by policy or technological changes. Results from the second application also show that ignoring the change in supply functions leads to significant underestimate of the welfare effects of biotechnological improvements in forestry.

K.-G. Löfgren (✉)
Centre for Environmental and Resource Economics, Department of Economics,
Umeå University, SE-901 87 Umeå, Sweden
e-mail: karl-gustaf.lofgren@econ.umu.se

P. Gong
Centre for Environmental and Resource Economics, Department of Forest Economics,
Swedish University of Agricultural Sciences, SE-901 83 Umeå, Sweden
e-mail: Peichen.Gong@slu.se

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11.1 Introduction

Models have always been a natural part of the development of economic theory. However, empirical applications of large scale econometric models were rare before the 1960s, when computers became capable of handling statistical analysis of large data sets. It is true that Heinrich von Thünen did important empirical work in the early 19th century, and that Jan Tinbergen, who together with Ragnar Frisch was the first to receive The Bank of Sweden Prize in Economics in Memory of Alfred Nobel, produced a large scale macroeconomic econometric model already in the 1930s (Tinbergen 1937). Tinbergen was indirectly criticized by Haavemo (1943) for handling the estimation of the system by ordinary least squares (OLS). This technique typically leads to biased estimates of the parameters in a simultaneous system. However, Bentzel and Wold (1946) showed that Tinbergen's system was recursive, and that OLS estimates would be unbiased. It was nevertheless true that recursive systems constituted a constraint for macro-econometric modeling. More general models needed new estimation techniques, such as two (three) stage least squares, and more potent numerical estimation techniques which were not available until the early 1960s. The rapid development of increasingly more powerful computers helped a lot. Econometricians were able to use maximum likelihood estimation techniques.

In the early 1970s Lawrence Klein started an international project with the aim to link national models to an international network. The project was called the Link project, and some of the very best economists participated in the project. The models that were built were intended to make counterfactual comparisons of different policy instruments. To start with optimism ruled, although it was not an easy task to identify the equations to be estimated. The identification problem was discovered already in the late 1920s by Tinbergen, and the necessary theory was developed long before the Link project started. Later Sims (1980) criticized the approach by claiming that there were too many relationships to be indentified and observations on exogenous instrumental variables were too few to solve the identification problem in a reasonable manner. He recommended instead vector autoregressive models (VAR-models).

A couple of years before Sims' contribution Lucas (1976) criticized the way counterfactual comparisons as such were handled. He pointed out that when policy changes, the economic behavior changes and hence both the structure and the parameters of the behavioral model may change. The model is estimated on historical data, conditional on past behavior, and when policy is changed counterfactually, there are no data to use to estimate the new model. Lucas claimed that existing models were too naive to predict the effects of a change in economic policy on the basis of relationships observed in empirical data. He suggested modeling based on deeper policy-invariant parameters like preferences, technology and resource constraints.[1]

Already in 1967/1968 Edward Phelps (1967) and Milton Friedman (1968) had shown why the so called Phillips curve failed. The Phillips curve was an empirical relationship between wage and price increases and unemployment that was estimated in 1958 by Alban William Housego Phillips on English wage and unemployment data from 1861 to 1957 (see Philips 1958). The curve indicated a trade-off between unemployment and inflation—the higher inflation the lower the unemployment. However, as soon as policy makers tried to exploit the trade off it disappeared. Phelps and Friedman showed that adaptive learning changed the position of the Phillips curve, and the unemployment level converged (ceteris paribus) to the initial level independent of whether the inflation was high or low. If it was high it remained high at the equilibrium unemployment level, and if it was low it remained low in steady state. This is the first model that indicated a “Lucas effect”.

The Lucas Critique has in economics been handled in different ways. Labor supply functions have been estimated by modeling the budget constraint using the tax system, and adding a shape of the labor supply function that has parameters that represent preferences (the utility function). The underlying technique was developed before the Lucas Critique surfaced (see for example Burtless and Hausman 1978). The parameters were estimated by using personal data about workers situation in the labor market as independent variables in the labor supply function and applied to the convex budget set. In macroeconomics the real business cycle school used explicit utility and production functions in which the parameters were typically calibrated from the initial state of the economy, or brought in from other econometric estimations (see Prescott 1986). The only forward looking data were typically price expectations. It is hard to understand how such a model can be used for counterfactual comparisons in real world situations. One can, of course, study what happens in the model if one parameter or a parameter vector is changed, but this is insufficient for conducting real world counterfactual comparisons.

A lot have been written about the Lucas Critique. Most of the discussion has focused on backward and forward looking macroeconomic models that are estimated from empirical data. The issue has been whether the Lucas Critique will show up in the sense that the parameters of the model, including policy parameters, will remain stable when policy changes. A forward looking econometric model differs from

[1] The statistical estimation of timber supply functions has been criticized by, among others, Binkley (1987). He claimed that the theoretical basis of the empirical models was week, and that the empirical data were poor. More importantly, for the present chapter, he pointed out that existing empirical timber supply functions describes the actual harvesting behavior within a given time period, and is conditioned on the ruling institutional setting. In other words, they have limited ability to evaluate policy and institutional changes. Binkley’s view is close to the more general Lucas critique.

backward looking models in the sense that it typically uses data about future expectations and deeper parameters that are derived from econometrically estimated utility functions, say as a byproduct of a labor supply model mentioned above. The present verdict seems to be that backward looking econometric models are on the average as good as forward looking models in terms of stable parameters (See Linde 2001 for details). But how can we find out if they can remain so for all data sets? The failure to reject the stability hypothesis across observed shifts does not insure that it will also be stable to shifts that have not yet occurred. Moreover, unfortunately statistical tests are such that we cannot prove stability, we can only fail to reject stability. For the above reasons Estrella and Fuhrer (1999) argue that the Lucas Critique is an empirically testable hypothesis in the sense that stability can be rejected.

Our numerical approach with parameterized supply functions can handle new data (information) and solve real world counterfactual problems. By avoiding estimating the key parameters ex ante, we produce a model where stability is not an issue. The counterfactual outcome is the difference between scenarios that are optimized with respect to the parameters, under given data and constraints. In other words, we are avoiding the Lucas Critique by not letting it creep into the model. Of course, we cannot be sure that the outcomes match potential real word outcomes.

Within forestry one of the most important concepts is timber supply or the timber supply function. Timber supply functions have been estimated by statistical methods at least since the late 1940s. Ruist and Svennilsson (1948) is an early Swedish reference. Initially, timber supply functions were typically estimated in a partial equilibrium environment and not from a large model covering an entire region or country. To date there exist both a large number of forest management models that maximize the profit and large global forest product models (for surveys see Wear and Parks 1994 and Gong and Löfgren 2009). The first type of models is typically linear or non-linear programming models that do not explicitly care about the shape of the supply curves. In the global trade model developed by Buongiorno et al. (2003) the methodology to determine the parameters of the model remind a lot about the ones used by the real business cycle people (calibration and "guessing"). The model has been used repeatedly to do counterfactual comparisons without caring too much about the Lucas critique. This may be understandable since the scope of the model as well as the number of parameters is large. However, the results from the counterfactual comparisons are most likely biased.

We claim that the forest sector has favorable characteristics in coping with the Lucas critique. There exist good inventory data and growth functions are relatively precise. Harvesting technology and cost data are, loosely speaking, known as are resource constraints. Preferences can, under the assumptions of certainty and perfect credit markets, be handled by alluding to Irving Fisher's separation theorem. Under these conditions one should be able to solve the intertemporal optimization problem under different scenarios and compare the profits and other aspects of the model, e.g. the number of cubic meters harvested at each instant of time. However, the model is not analytically solvable so structure will be missing.

In particular, closed-form supply functions cannot be derived by solving the intertemporal optimization model.

Without having heard about the Lucas critique, Gong (1994, 1995) used the above mentioned advantages to develop an alternative method for counterfactual comparisons. The method avoids most of the Lucas critique. The idea is to use the fact that any function can be approximated by a Taylor expansion. The parameters of such an expansion are parameters of the derivatives of the expansion measured at the point of expansion. The trick parameterizes the harvest behavior functions (the supply function), which can be plugged into the (expected) present value function and optimized with respect to the parameters. In this manner the optimization model produces structure in terms of, among others, supply functions. Moreover, any new "policy" in terms of a constraint, a tax and some other change of the model can be handled by re-optimizing the model, which gives a new value of the optimal value function as well as a new supply function (new parameters).

11.2 Large Scale Applications in the Swedish Forest Sector

The original papers by Gong (1994, 1995) illustrate how to produce approximations of behavior functions associated with a given policy and institutional setting without conducting any counterfactual comparisons. In this paper we sum up two counterfactual studies that have been done using this method. One of the studies (Gong et al. 2012) deals with biotechnological progress in the form of a once forever increase in the productivity of forest land in Sweden. The total social surplus of timber production in Sweden when improved genetic materials are used is compared with a status quo scenario. This analysis covers all the forests in Sweden below the age of 120 years and assumes that the use of improved genetic materials increases the productivity of forest land by 40 %. The other study (Gong and Löfgren 2003) assesses the total surplus generated by the non-industrial private forests in Sweden (the total area is about 11.5 million ha) under monopoly and under perfect competition, respectively, and estimates the resulting gain for society from perfect competition. Both studies explicitly incorporate uncertainty in future timber demand, but ignore the effect of timber production on the non-timber benefits of the forests.

We will focus on the theoretical model underlying the first study, and some of the relevant empirical details of the second. Since the theory and the empirical details are similar in the two cases, we will gain time and space.

11.3 The Value of Biotechnological Progress

Tree improvement programs increase the productivity of forest land and affects both forest owners and "timber consumers". For the forest owners the trees will grow faster and they will be able to produce more output. However, (ceteris paribus) the market prices could be lower due to the increased supply of timber. The financial consequences depend on the relative magnitudes of the increase in yield and the decrease in prices. The consumer surplus will increase since the timber processing industry and other users of the timber can purchase a larger amount of timber at lower prices.

When improved regeneration material (IRM) is introduced the anticipated changes in the productivity of forestland and in timber prices would typically lead to changes in silvicultural practices and rotation ages, both for existing stands and for stands to be established using the IRM. This means that the relationship between timber supply and factors affecting the optimal harvest decisions may change. Under the assumption of rational behavior, forest owners will change their management decisions in order to increase their gains (or reduce their losses) resulting from the use of IRM. If the market leads to a socially optimal allocation of the resources, the change in forest management behavior in response to the presence of IRM would increase the social welfare.

The counterfactual experiment is conducted on a large scale application to the Swedish forest sector. The total area covered in the analysis is 20 million ha, which includes all the productive forests in Sweden under the age of 120 years. An implicit assumption is that the existing forests which are older than 120 years (about 3 million ha) shall be managed for non-timber benefits (biodiversity conservation, recreation, etc.) and thus are excluded from the analysis. It is assumed that forests regenerated using the IRM will grow 40 % faster than the existing ones as measured in terms of the maximum mean annual increment, independent of site quality. Further, we assume that the growth effect of the IRM is known with certainty. This assumption implies that, when the timber market is competitive, all forest owners shall rationally choose to regenerate all harvested site using the IRM, even if this may lead to reduced profits.[2]

The objective is to maximize the expected present value of the total economic surplus, i.e. the intertemporal sum of the discounted producer and consumer surplus both in the absence and in the presence of genetic progress. Maximizing the present value of current and future profits is an often used, but not self evident, objective function even under certainty. It implies that the model builder assumes that the capital market is perfect, i.e. the borrowing and lending rates are the same and that there is no credit rationing. This assumption guarantees that Irving Fisher's separation theorem holds and that investment projects can be ranked independent of the preferences of the investor. Under conditions of uncertainty, the assumption of a perfect capital market alone is insufficient for assuring the present value to be a proper objective function, as investors may have different attitudes to risk. Assuming that the forest owners are risk neutral would enable us to invoke Fisher's separation theorem and maximize the expected present value of current and future harvests.

[2] From the perspective of each forest owner, regeneration using the IRM will result in a greater yield of timber, but will not affect the timber price when timber market is competitive. Thus, each forest owner can increase his/her profits (or reduce the loss) by changing to the IRM after an existing stand is harvested, irrespective the decisions of the other forest owners.

We assume that the introduction of the IRM will not affect the timber demand function. On the other hand, timber demand in each future period is subject to the influence of factors that are not known with certainty beforehand. The inverse demand function in time period t is $P(Q_t, B_t) = \beta_t^1 (Q_t)^{\beta_t^2}$, where Q_t denotes the amount of timber demanded in period t, $B_t = (\beta_t^1, \beta_t^2)$ is a vector of stochastic parameters of the demand function in period t. The probability distribution of B_t is assumed to be known. The supply function is modeled as:

$$S(I_t, p_t; A) = e^{\alpha_1} (I_t)^{\alpha_2} (p_t)^{\alpha_3},$$

where $A = (\alpha_1, \alpha_2, \alpha_3)$ is a vector of the supply function coefficients to be determined through optimization, I_t is the growing stock of timber at the beginning of period t, and p_t is the price of timber in period t. We assume that all forest owners are risk neutral and determine the coefficients of the market supply function by maximizing the expected present value of the total surplus over time. The supply parameters are determined from the following constrained maximization problem:

$$\max_A \quad E[TS(A)] = E\left[\sum_{t=1}^{\infty} \left(\int_0^{Q_t} P(q; B_t) dq - C(X_t, Q_t) \right) e^{-rt} \right] \tag{11.1}$$

Subject to

$$\begin{aligned} p_t &= P(Q_t; B_t) \\ Q_t &= S(I_t, p_t; A) \end{aligned} \tag{11.2}$$

$$I_t = V(X_t) \tag{11.3}$$

$$X_{t+1} = G(X_t, Q_t) \tag{11.4}$$

$$X_1 = X_0 \tag{11.5}$$

where

E	is the expectation operator.
$TS(A)$	the present value of total surplus.
$C(X_t, Q_t)$	forest management and harvest costs as a function of the state of the forests and the harvest level.
Q_t	the market supply and demand for timber at time t.
p_t	the market price of timber at time t.
X_t	the age-class distributions of the forests at time t.
X_0	the initial age-class distributions of the forests.
r	discount rate.
I_t	$V(X_t)$ is the growing stock of timber associated with the age-class distributions of the forests at time t.
$G(X_t, Q_t)$	the growth function of the forests.

Constraint (11.2) is the market clearing condition. Equation (11.3) defines the growing stock of timber conditional on the age-class distributions of the forests. Constraint (11.4) describes the dynamics of the forests. Equation (11.5) gives the initial state of the forests. Of course, the total harvest at each point in time cannot exceed the total growing stock of timber in the forests. This constraint is included in the supply function. The expected present value (EPV) of the total surplus is estimated by taking the average of a large number of demand scenarios, each scenario represents a series of random draws from the distributions of B_t. In other words, we have to rely on a numerical approximation.

Let $\left[B_1^k,\ B_2^k,\ \ldots,\ B_T^k\right]$denote the coefficients of the demand function in years 1 to T in scenario k, where B_t^k is a random sample drawn from the distribution of B_t. A numerically tractable version of the optimization problem (11.1)–(11.5) can be formulated as:

$$\max_A \quad E[TS(A)] = \frac{1}{N}\sum_{k=1}^{N}\left[\sum_{t=1}^{T}\left(\int_0^{Q_t^k} P(q;\ B_t^k)dq - C(X_t^k,\ Q_t^k)\right)e^{-rt} + R(X_{T+1}^k)\right] \tag{11.6}$$

Subject to

$$\begin{aligned} p_t^k &= P(Q_t^k;\ B_t^k), \qquad \text{for } t = 1\ldots T;\ k = 1\ldots N \\ Q_t^k &= S(I_t^k,\ p_t^k;\ A) \end{aligned} \tag{11.7}$$

$$I_t^k = V(X_t^k) \quad \text{for } t = 1\ldots T;\ k = 1\ldots N \tag{11.8}$$

$$X_{t+1}^k = G(X_t^k,\ Q_t^k), \quad \text{for } t = 1\ldots T;\ k = 1\ldots N \tag{11.9}$$

$$X_1^k = X_0, \quad \text{for } k = 1\ldots N \tag{11.10}$$

where N is the number of demand scenarios used to estimate the EPV of the total surplus, T is the time horizon within which the annual harvest of timber is determined using the supply function, Q_t^k is the market supply (and demand) of timber in year t in scenario k, p_t^k is the market price of timber in year t in scenario k, X_t^k is the state of the forests in year t in scenario k, and $R\left(X_{T+1}^k\right)$ is the present value of the forest in year $T+1$. To be specific, the term $R\left(X_{T+1}^k\right)$ represents the sum of the discounted total surplus the forests will generate from year $T+1$ and onwards. That is:

$$R\left(X_{T+1}^k\right) = E\left[\sum_{t=T+1}^{\infty}\left(\int_0^{Q_t} P(q;\ B_t)dq - C(X_t,\ Q_t)\right)e^{-rt}\right]$$

Denote the forest growth function in the absence and in the presence of the IRM by $G^b(X_t, Q_t)$ and $G^n(X_t, Q_t)$, respectively. By solving the optimization model (11.6)–(11.10) using the growth function $G^b(X_t, Q_t)$ we obtain the coefficients of the timber supply function and the EPV of the total surplus in the absence of the IRM. Denote this optimal solution by A^b and $E[TS^b(A^b)]$. Similarly, if the growth function $G(X_t, Q_t)$in Eq. (11.9) is replaced by $G^n(X_t, Q_t)$, then the optimal solution of problem (11.6)–(11.10) gives us the coefficients of the timber supply function and the EPV of the total surplus in the presence of the IRM. Denote this optimal solution by A^o and $E[TS^o(A^o)]$. The difference between these two EPVs of the total surplus $E[TS^o(A^o)] - E[TS^b(A^b)]$, gives the total welfare effect of using the IRM.

The total welfare effect can be decomposed into the direct effect of using the IRM and the effect of changing harvest behavior induced by the use of the IRM. To this end we need to estimate the EPV of the total surplus in the situation where the IRM is used in regeneration but forest owners do not change their harvest behavior, i.e. the EPV of the total surplus associated with the new forest growth function and the baseline supply function. Denote this EPV by $E[TS^n(A^b)]$. The direct welfare effect of using the IRM is $E[TS^n(A^b)] - E[TS^b(A^b)]$ and the effect of changing harvest behavior is $E[TS^o(A^o)] - E[TS^n(A^b)]$.

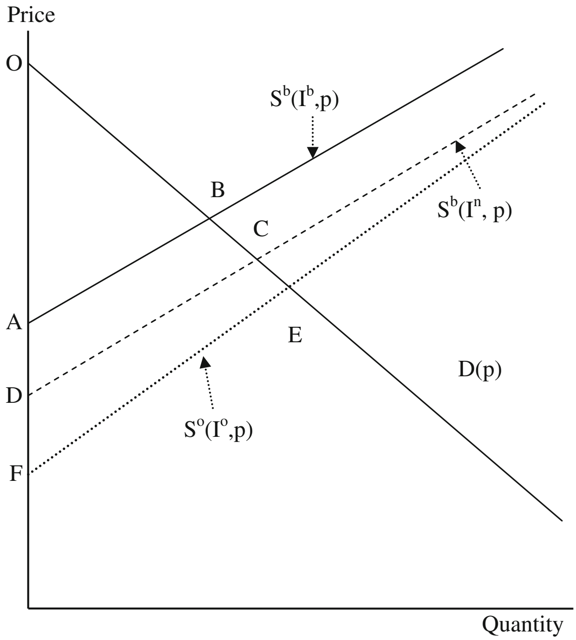
Schematically we can look at the result in terms of a one period version of the market solution given in Fig. 11.1. The downward sloping curve $D(p)$ is the demand curve, which shifts stochastically over time. The upward sloping curves are all supply curves. $S^b(I^b, p)$ is the baseline supply curve with inventory I^b. The dotted curve $S^b(I^n, p)$ is the baseline version of the model conditional on the new inventory I^n generated by the new genetic material. In other words, the structural equations contain the baseline parameters. Finally, the curve $S^o(I^o, p)$ is the re-estimated supply curve that contains new parameters that are generated by the change in harvest behavior induced by the improved tree material.

We can now relate the estimation of the expected present value of the total surplus to Fig. 11.1. The expected present value of the total surplus when we introduce the IRM, but use the supply function parameters of the baseline case, $E[TS^n(A^b)]$, corresponds to the area DOC. The area ABCD is the direct effect of using the IRM on welfare. And the area DCEF is the effect of changing harvest behavior on welfare. This term measures the result of the attempt to avoid the "Lucas critique".

11.4 Results from Gong et al. (2012)

What in particular interests us is the magnitude of the effect of changing harvest behavior mentioned above, which represents the change in the total surplus when we compute the total surplus under the IRM with baseline coefficients and the total surplus when we re-estimate the coefficients to embed the effect from a change in

Fig. 11.1 A schematic market solution



harvest behavior in the parameter estimates. In the analysis, the two coefficients of the demand function β^1 and β^2 were assumed to be independently distributed normal variables. The mean value was 473,610 for β^1 and -1.67 for β^2. The standard deviations of the two parameters were set to 10 % of their mean values. The time horizon was set to 200 years ($T = 200$). 100 randomly generated demand scenarios were used in the optimization of the supply function coefficients ($N = 100$). The lowest allowable harvest age is 60 years. The harvest cost was 95 SEK/m^3, and a real interest rate of 3 % was used.

The results are summarized in Table 11.1. When estimated using the baseline case supply function, the EPV of the total surplus would increase by 27.4 billion SEK following the use of the IRM. If the supply function coefficients are re-optimized after the introduction of the IRM, then the use of the IRM would increase the EPV of the total surplus by 33.61 billion SEK. Accordingly, the gain from changing harvest behavior is 6.2 billion SEK or 18 % of the total effect. In this application the change in harvest behavior leads to a significant increase in the expected present value of the total surplus. Here the Lucas critique bites!

Table 11.1 shows that after the introduction of the IRM the producer surplus decreases, while the consumer surplus increases. The reason is that the use of the IRM increases supply, while the expected demand curve is assumed to be stationary. From the perspective of a forest owner who behaves as price taker, the use of the IRM would increase future timber yield without affecting the price. Thus, in a competitive market forest owners would use the IRM in regeneration following the harvest of existing stands. When a large number of forest owners use

Table 11.1 The expected present values of producer surplus and consumer surplus in the presence of the IRM

	Producer surplus	Consumer surplus	Total surplus
Baseline supply function	596.72	21908.75	22505.47
	(−30.10)	(57.50)	(27.40)
Optimal supply function	583.35	21928.31	22511.66
	(−43.45)	(77.06)	(33.61)

Note Figures in parentheses give the change from the case where the IRM is not available
Unit billion SEK

the IRM, the timber supply curve would shift downwards to the right, causing the market equilibrium price of timber to decrease. Depending on the price elasticity of timber demand, the decrease in timber price could be large enough to overweigh the increase in yield and thus the producer surplus could decrease. On the other hand, the shift in the supply curve caused by the use of the IRM could stimulate the demand for timber in the future. The increase in future timber demand would alleviate the reduction in producer surplus resulted from the use of the IRM. Technically we can add a time trend in the demand function, but it would not change the basic methodological message.

11.5 Monopoly Versus Perfect Competition

Another large scale application of the method in the same mode as is in the previous section is an attempt to evaluate what a monopoly roundwood market means in terms of economic welfare relative to perfect competition. The analysis is confined to the harvest decisions of non-industrial private forest owners in Sweden. While the market regimes we chose to compare may be criticized for being unrealistic, they serve our purpose of conducting counterfactual comparisons. Moreover, since monopoly and perfect competition are two polar cases of free markets, the result of the comparison provides us with an upper bound for the social loss from imperfect competition.

11.5.1 The "Supply Function" Under Monopoly

Again the idea is to estimate parameters of the "supply functions" that belong to the two regimes. To avoid being called microeconomic charlatans, let us already at this stage say that we know that there is no supply curve under monopoly. This fact gives the application of our method an extra flavor. We will also, as in the previous case, assume that stochastic shocks are introduced by a shifting stationary market demand function. Since a stochastic regime under general conditions introduces the properties of forest owners into the picture, we will for simplicity assume that forest owners are risk neutral. This assumption will again enable us to invoke Fisher's separation theorem.

The lack of a supply function under monopoly creates technical problems. A simple way to proceed is to assume that the demand function has a linear shape:

$$D_t(p_t) = \alpha_t - \beta p_t \tag{11.11}$$

Where α_t is a stochastic parameter which determines the position of the demand curve at time t and β is a positive constant telling us the slope of the demand curve. Denote I_t as the size of the growing stock of timber. Assuming that the marginal harvest cost function does not change over time and that the interest rate is also fixed, we can express the optimal harvest level at time t as a function of α_t and I_t:

$$s_t^m = h(\alpha_t, I_t) \tag{11.12}$$

Under monopoly the market price of timber is determined by the demand function and the harvest volume. By substituting the optimal harvest volume (11.12) into the demand function (11.11), we can solve the demand function for the optimal (market) price in period t:

$$p_t^m = [\alpha_t - h(\alpha_t, I_t)]/\beta \tag{11.13}$$

Figure 11.2 illustrate how the optimal harvest and price of timber change following a parallel shift of the demand curve (i.e. when α_t changes), assuming that the timber inventory before harvest I_t is given. As we restrict ourselves to parallel shifts in the demand function, we can express the relationship between the optimal harvest level and the timber price by a monopolistic "pseudo-timber supply function":

$$s_t^m = S^m\left(p_t^m, I_t\right) \tag{11.14}$$

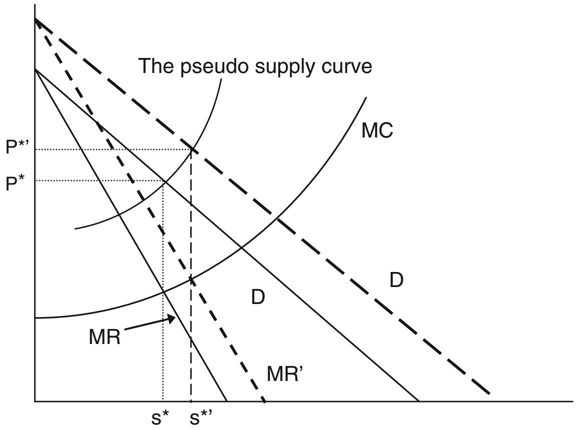
This function describes the timber supply under monopoly as a function of the market price and the size of the growing timber stock. The supply and price of timber should of course also satisfy the demand function (which is the market clearing condition under monopoly), i.e.

$$S^m\left(p_t^m, I_t\right) = D_t\left(p_t^m\right) = \alpha_t - \beta p_t^m \tag{11.15}$$

11.5.2 The Supply Function Under Perfect Competition

Under perfect competition the demanders and suppliers are price takers and aggregate demand and supply determine market supply and the equilibrium market price in each time period. The supply from the competitive forest owners in period t is determined by the maximization of the present value and the supply function will be a function of the interest rate, the harvesting cost, the market price and the growing

Fig. 11.2 Optimal decision under monopoly (Adopted from Gong and Löfgren 2003)



stock of timber. Since we assume that the interest rate and the harvesting cost are constant, we can preferably hide them in the supply function and write:

$$s_t^c = S^c(p_t, I_t) \tag{11.16}$$

The knowledge of the timber supply function enables the forest owner to determine the optimal harvest level based on the prevailing timber price and the growing stock of timber.

11.6 Determining the Optimal Supply Function

The monopolistic pseudo supply function, as well as the supply function under perfect competition, is approximated by first choosing a parametric functional form and then optimizing the values of the parameters. The supply functions are given the same functional form

$$s_t = a_1 + a_2 p_t + a_3 p_t^2 + a_4 I_t + a_5 p_t I_t \tag{11.17}$$

Except for the absence of I_t squared, the shape is a second order Taylor expansion.

The technicalities behind the optimization are not trivial, but we will here stay with a schematic description of the process. The details are available in Gong and Löfgren (2003). We will here discuss the relevant steps in both optimization problems, and we start with the monopoly case. The coefficients of the monopolistic pseudo supply function are optimized by maximizing the EPV of the forests. Given a supply function the EPV is estimated by simulating the timber demand over time. Since we assume risk neutral forest owners the maximum EPV describes the optimal harvest behavior under monopoly.

In a perfectly competitive timber market, and in the absence of a complete set of forward markets, the optimal harvest decisions and thus the short-run timber supply function depend on the forest owners' expectations of future prices. These can be formed in different ways and there may be many optimal solutions. We pick the one that is socially optimal and determine the coefficients of the aggregate supply function under perfect competition by maximizing the expected present value of the total surplus, $E[TS(A)]$. Given a supply function with parameter vector A, the $E[TS(A)]$ is estimated by simulating the timber demand and the associated market equilibrium supply. This method of determining the optimal supply coefficients is equivalent to maximizing the EPV of the forests with endogenously determined future price distributions. Price expectations are rational in the sense that the price distributions used to calculate the EPV coincide with the distribution of market equilibrium prices in future periods.

The solution of the competitive problem is similar to the problem in Eqs. (11.6)–(11.10), while the monopoly problem uses a slightly different stance, since the optimal solution only handles the expected profit of the firm and not the consumer surplus. To obtain the total surplus under monopoly, one has to add the expected consumer surplus under the inverse demand curve.

11.7 The Data and Some Further Assumptions

The pseudo-timber supply function under monopoly and the aggregate supply function under perfect competition are estimated by using data from the forest endowments of the non-industrial private forest owners in Sweden. The total endowment encompasses 11.485 million hectares. We have excluded the old growth part of the forest, defined as stands with trees exceeding 120 years. The economic argument for this choice is that it is most likely to keep these stands intact because of their high non-timber values. The readers may like to refer Gong and Löfgren (2003) for detailed discussion.

Our analysis abstracts from the species composition and the site quality distributions, only age matters. The lowest permitted harvest age is put to 65 years and the highest is 120 years. With respect to thinning we classify stands from 40 up to 60 years as "thinning stands". The annual thinning volume is calculated by multiplying the total area of these stands by the average thinning intensity. We assume a uniform age distribution of the forest in each age-class. Based on data from the existing age-class distribution of the forests the timber yield function is estimated to be

$$V(t) = -71.3 + 6.73t - 0.038t^2 \tag{11.18}$$

The linear demand function for timber is borrowed from Hultkrantz and Aronsson (1989) and has the following shape:

$$D_t(p_t) = 83.3 - 1.11p_t + \varepsilon_t \tag{11.19}$$

The random term ε_t is normally distributed with zero mean and we add truncation points at +/-2σ. The standard deviation is set to 9.66 million m^3, which corresponds to a 20 % standard error of the timber price at the average supply. We also show results for a standard deviation that is 50 % down (up) from the baseline standard deviation.

To be consistent with the estimation of the timber demand curve, management costs were deflated to the price level for 1964, which is where the Hultkranz and Aronsson's data series started. The time horizon was set to 150 years and 100 timber demand scenarios were used in the optimizations of the supply function coefficients, in the competitive as well in the monopoly regime. After we have obtained the optimal supply function coefficients, the total social surplus was re-estimated using 1,000 randomly generated demand scenarios.

11.7.1 The Results

We will in this section focus on the resulting differences between the two solutions. This will be done by reproducing some of the main result from Gong and Löfgren (2003). We treat the two cases simultaneously and produce the range of prices and quantities split up into an uncertainty dimension. More precisely, we measure the min and max, as well as the means of both prices and quantities under three different scenarios, low, baseline and a high standard deviation of the timber demand. We also produce the expected present values under the three scenarios. The results for the monopoly case are listed in Table 11.2.

The results show that a higher level of timber demand uncertainty leads to a wider range of optimal timber prices and larger variations in timber supply. The EPV of current and future profits increases when demand uncertainty increases. The results follow if the optimal value function is convex with respect to the parameters of the model and Jensen's inequality.

Table 11.3 presents the corresponding results under perfect competition. For each level of timber demand uncertainty the simulation has been conducted using the same set of demand scenarios as were used in the monopoly case. Hence the results are comparable to the ones produced by the pseudo supply function in the monopoly case.

The effect of an increasing uncertainty is also in this case a wider range in prices and quantities, as well as in the EPV. This follows if the expected optimal value function is globally convex in the relevant parameters of the model.

A comparison of Table 11.2 with Table 11.3 shows that, regardless of the level of timber demand uncertainty, the expected timber supply in the competitive market is significantly higher than in the monopoly market. Moreover, competition in the timber market leads to a lower expected market price and a lower EPV of the market equilibrium profits. This means that our results are consistent with those from the standard economic theory. Note, however, that we are dealing with a renewable resource, which means that the difference between the monopoly price and the competitive price is non-standard (see e.g. Dasgupta and Heal (1979) Chap. 11).

Table 11.2 Prices, quantities and EPV under monopoly (Adopted from Gong and Löfgren 2003)

	Timber demand uncertainty		
	Low	Base case	High
Timber price (SEK/m^3)			
Min	44.14	39.02	35.25
Mean	49.19	49.16	48.97
Max	54.20	59.38	63.46
Annual timber supply (million m^3)			
Min	23.14	19.15	13.54
Mean	28.47	28.51	28.71
Max	33.79	37.83	43.77
Mean clear cut (million m^3)	22.95	22.97	23.16
Mature timber stock (million m^3)			
Min	616.97	586.04	552.60
Mean	804.11	802.78	794.91
Max	950.11	984.51	1025.35
EPV of producer surplus (million SEK)	23,229	23,600	24,241

Table 11.3 Prices, quantities and EPV under perfect competition (Adopted from Gong and Löfgren 2003)

	Timber demand uncertainty		
	Low	Base case	High
Timber price (SEK/m^3)			
Min	30.67	29.17	30.18
Mean	37.96	38.14	38.46
Max	59.53	68.81	89.65
Annual timber supply (million m^3)			
Min	25.62	19.59	9.11
Mean	40.99	40.78	40.42
Max	58.63	69.77	78.09
Mean clear cut (million m^3)	33.51	33.36	33.04
Mature timber stock (million m^3)			
Min	19.20	11.46	1.02
Mean	182.81	200.59	217.41
Max	822.55	822.55	823.83
EPV of producer surplus (million SEK)	15,633	15,922	16,160

Finally, we move to present the welfare gain from a change in the market regime from monopoly to perfect competition. Here we have to compare the expected total surplus under both regimes. These were estimated with the same set of 1,000 timber demand scenarios over a time horizon of 150 years. The results are summed up in Table 11.4.

Again we note that the optimal expected values of the surpluses increase with a higher degree of uncertainty which we would expect if the optimal total surplus

Table 11.4 The expected present value of social surplus (million SEK) (Adopted from Gong and Löfgren 2003)

Timber demand uncertainty	Monopoly market	Competitive market[a]
Low	35,048	43,496 (24.1 %)
Base case	35,543	44,145 (24.2 %)
High	36,594	45,279 (23.7 %)

[a] Values in parentheses are the percentage gain over monopoly

inherits convexity from the shifting demand curve. The total gain from perfect competition in comparison with the total surplus from monopoly is 24 %. This must be considered as an upper bound. In reality a complete set of forward markets does not exist and forest owners will have to determine the optimal harvest volume based on exogenously formed expectations of future prices. In other words, perfect competition in the timber market does not typically lead to a first best value of the expected social surplus.

11.8 Conclusions

The two studies summarized above show that one can assess the impacts of policy and institutional changes as well as technology progress on the managerial behavior of forest owners by directly examining their rational behavior in the relevant contexts. This approach builds on the properties of rational behavior. It requires information about the dynamics of the forest and about the factors that affect the optimal decision of forest owners, but does not need data about the observed behavior. This approach enables us to avoid most of the Lucas critique in counterfactual comparisons. Moreover, the two studies indicate that the welfare effect of changing managerial behavior following a policy or institutional change could be substantial. The standard method for forest policy evaluation based on econometric models could therefore lead to significantly biased estimates of the welfare effect of policy or institutional changes.

The method we employed in the two studies is in essence optimization of the market supply of timber. A unique feature of our method is that we describe timber supply as a function of both timber price and the growing stock of timber. Timber supply is optimized indirectly by optimizing the supply function. In other words, we use a continuous function to approximate the optimal supply of timber. Thus the method can be viewed as a heuristic method for solving the timber market model. One advantage of this method is that it leads to substantial simplification of the optimization problem. More importantly, the supply function obtained serves as an adaptive harvest decision strategy when timber demand or the dynamics of the forest is not known with certainty. Our method is similar to the econometric approach in the sense that one need to specify the functional form of the supply function based on the analytical properties of optimal supply. The method differs from the econometric approach in the way the coefficients of the supply function are determined. From this perspective, the method is just an alternative method of determining the supply function. Applications of the method are so far limited to a few case studies. However, we believe that the method can be applied to a wide range of forest policy analyses.

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Chapter 12
Multiple Forest Stocks and Harvesting Decisions: The Enhanced Green Golden Rule

Shashi Kant and Chander Shahi

Abstract The concept of the Green Golden Rule (GGR), introduced by Chichilnisky et al. (1995), which refers to the configurations of the economy that give the highest indefinitely maintainable level of instantaneous utility, is extended to forest resources. Generally, a forest has multiple types of stocks/cohorts—stocks of different ecological attributes and age classes—that provide different goods and services, and these goods and services are valued differently by different user groups. Hence, the aggregation of all stocks into a single stock is unable to capture the complexities of forest growth, user groups' preferences, and their implications for sustainable management of these resources. Sustainable management of forest resources requires optimal consumption as well as an optimal level of conservation of each type of stock separately. We develop optimal conditions for conservation and consumption for a forest comprised of three differentiable stocks, and generalizes these conditions for any number of stocks greater than three. We term these conditions as the Enhanced Green Golden Rule (EGGR). The EGGR provides more distinct optimality conditions than the GGR for all stocks except the terminal stock. We demonstrate the applications and implications of the EGGR for logistic growth functions of three types of forest stock having a Cobb-Douglas utility function of forest consumption and conservation.

S. Kant (✉)
Faculty of Forestry, University of Toronto, 33 Willcocks Street, Toronto, ON M5S 3B3, Canada
e-mail: Shashi.kant@utoronto.ca

C. Shahi
Faculty of Natural Resources Management, Lakehead University, 955 Oliver Road, Thunder Bay, ON P7B 5E1, Canada
e-mail: cshahi@lakeheadu.ca

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12.1 Introduction

The main focus of Faustmann forest economics has been on the determination of an optimal forest rotation, and the Faustmann formula has been termed as forestry's golden rule by Newmann (2002). Probably more than 500 papers have been published on this subject in the last 3 decades, and the most comprehensive approach has been presented in the generalized Faustmann model by Chang (1998). Most of these chapters have addressed an optimal forest rotation for a single stand and the value of timber only. Hartmann (1976) included non-timber values for a single stand, and many chapters have followed and extended Hartmann's model but mainly to a single stand case. In addition, Hartman's model and its extensions included only the consumption value, measured in monetary units, of non-timber products, and ignored any amenity values due to the stock of forest.

The importance of multiple stands (mainly in terms of multiple age classes) in a forest and interdependencies between multiple stands has been recognised by some resource economists. Swallow and Wear (1993) and Koskela and Ollikainen (2001) examined landowner decisions in the presence of interactions between two or more adjacent stands. Another stream of chapters has included age-class dynamics in studies of landowner behaviour; some focused on timber benefits only (Berck 1976, 1979; Mitra and Wan 1985, 1986; Sedjo and Lyon 1990; Salo and Tahvonen 2002, 2003; Khan and Piazza 2011) while others included timber and non-timber benefits (Bowes and Krutilla 1985, 1989; Uusivuori and Kuuluvainen 2005). In the age-class dynamics category, there is another stream commonly known as the economics of uneven-aged forest management or selection harvesting, and recent studies in this stream include Chang and Gadow (2010) and Xabadia and Goetz (2010). However, this last stream has focused only on consumption values from timber and in some cases non-timber products.

In short, most of forest economics literature addressing harvesting decisions is focused on the utility derived from the monetary value of either timber only or in some cases timber and non-timber products. There are very few exceptions that have included the utility from the amenity value of forest stock. For example, Bowes and Krutilla (1985, 1989) included the amenity value of forest stock in the objective function but simply added it to the revenue from forest harvesting, and implicitly assumed that there is no economic flaw in adding the amenity value's economic measure (willingness to pay) to the price of timber. In fact, market price is determined by the interactions between demand and supply while willingness to pay, irrespective of its other limitations, simply reflects the demand curve, and therefore the sum of the two is similar to the sum of apples and oranges. Uusivuori and Kuuluvainen (2005) separated utility from timber harvesting and the amenity utility from the forest stock, and assumed the amenity utility as a function of the volume of biomass, but did not distinguish between the possible differences in the amenity utility from different types of stands. In the forestry literature, it is well recognised that different forest stands, distinguished on the basis of either age or other physical and biological characteristics such as biodiversity and habitat, provide different amenity values, not due to the difference in biomass volume only but due to the different physical and biological features of each stand.

Second, all these studies have focused on the conceptualized state of the forest called the "normal forest", which means that forestland is evenly distributed over age-classes. This concept of a normal forest may be a useful concept, but it is an idealistic and unrealistic concept similar to the concept of a perfect market in economics. Even the usefulness of the normal forest concept is being restricted by the emerging concepts of the new forest management regime known as "ecosystem-based" forest management, "near-natural" forest management, "continuous cover" forest management, or sustainable forest management. This new forest management regime looks for a "near-natural" state and not for the ideal state of the normal forest. One of the common approaches of this new forest management regime is multiple-cohort forest management that attempts to emulate a natural age structure and composition of forest across a given land base. The rationale behind multiple-cohort management is that emulation of structures resulting from natural processes favours the maintenance of biodiversity and ecological functions (Bergeron et al. 1999).

Third, other most common feature of these studies is the maximization of the discounted net revenue or utility using a constant discount rate, a criterion known as the discounted utilitarian criterion. This criterion has been challenged by many economists in the context of sustainability, specifically with reference to intergenerational equity. Finally, in most of these chapters, the prices of timber are assumed to be the same for timber coming from different age classes, implying that the marginal utility from timber consumption from different age-classes is the same. This assumption is also far from reality. Hence, there is a need for a new economic approach for forest harvesting decisions that addresses the above discussed four limitations of existing approaches.

The concept of sustainability, which is the key in sustainable forest management, has attracted the attention of many mainstream economists. The contributions of Dasgupta and Heal (1974, 1979); Stiglitz (1974) and Solow (1974) are some of the early contributions, but Hartwick's rule or the Weak Sustainability approach (Hartwick 1977, 1978a, b) is one of the more common contributions despite its limitations demonstrated by Asheim (1986) and others. This early literature on sustainability considered utility to be a function of natural resources consumption only. The next wave of chapters included "resource stock" as a source of utility in addition to consumption of this stock. Krautkraemer (1985) developed a model for non-renewable resources and Beltratti et al. (1993)

extended Krautkraemer's work for both non-renewable and renewable resources using Chichilnisky's criterion of maximizing the weighted sum of the present and long run values of utility. In the case of non-renewable resources, they found that for maximum sustainable utility, conservation of the entire stock is the optimal solution, which leads to equal treatment for present and future generations. However, their analysis of a renewable resource suggests that the problem does not have a solution because of the conflict between benefits for present and future generations. Hence, they used a declining discount rate which asymptotically converges to zero to solve this problem. Chichilnisky et al. (1995) characterized this state of economy as the Green Golden Rule (GGR) and found that the solution to the discounted utilitarian criterion discriminates against future generations, whereas the GGR accounts for future generations using the solution to the problem of maximizing long-run utility.

The GGR is an extension of the Golden Rule (GR) of economic growth, established by Meade-Phelps-Robinson, which refers to a growth path of the highest maintainable level of consumption per head (Phelps 1961) while the GGR refers to the highest indefinitely maintainable level of utility—which includes utility from consumption as well as the stock of environmental and/or natural resources (Chichilnisky et al. 1995). Hence, the GGR is a valuable contribution to the economic literature on issues related to sustainability due to its incorporation of intergenerational equity and utility from the natural resource stock. However, the GGR is insensitive to the diversity of natural resource stocks and different utilities derived from them—either by consumption or by the stock itself; this results in the limited applications of the GGR to the real problems of natural resource management.

In this chapter, we enhance the GGR by incorporating the diversity of forest resource stocks and utilities from them, and apply that concept to determine harvesting rules for different types of forest stocks. We call this approach the Enhanced Green Golden Rule (EGGR). The EGGR addresses all the four limitations, identified in the previous paragraphs, related to the literature on optimal forest rotations. It recognizes multiple-cohorts or multiple stands of forests, and incorporates the utilities from timber consumption and amenities from the each stand/cohort separately. The EGGR model, presented in this chapter, is based on utilities and not on market prices and/or willingness to pay, and therefore it overcomes the problem of adding market prices and willingness to pay together. The EGGR model also avoids the use of the discounted utilitarian concept and the use of the same market prices for timber from different stands/cohorts.

The EGGR is, first, developed for a forest resource of three cohorts/stocks. For simplicity we categorize the forest in three cohorts/stocks based on age—young, mature and old cohorts/stocks. Using the results of the EGGR for three cohorts/stocks, a generalized EGGR is presented for any number of cohorts/stocks of the forest resource. The outcomes of the EGGR—optimum levels of consumption and conservation of multiple stocks of a forest resource—are illustrated by an example. We have used age as a criterion for classifying the cohorts for simplicity, and our results are applicable to the classification of cohorts/stocks based on any other criterion such as biodiversity, habitat, or any other useful characteristic.

Next, in Sect. 12.2, we introduce the growth structure of a three cohort forest resource. In Sect. 12.3, we present the EGGR for a forest resource of three cohorts/ stocks, and the generalized EGGR for any number of cohorts. An illustration of the outcomes of the EGGR is provided in Sect. 12.4, and in the last section, some concluding remarks are put forward.

12.2 The Growth Structure of Multiple Cohorts of a Forest

Forest resources provide multiple products and services, such as timber, fuelwood, fodder, recreation, biodiversity, wildlife habitat, carbon sequestration, watershed services, esthetic values, cultural and spiritual values, and Aboriginal values. All these products and services are not equally valuable to different sections of a society. For example, environmentally-oriented groups and Aboriginal people may place higher values on biodiversity, wildlife habitat, and cultural values, recreation groups on recreation services, economic-growth oriented groups on timber values, and forest-dependent groups in developing countries on fuelwood and some non-timber products. The production of these goods and services depends on various attributes of forests such as composition in terms of species and size and distribution of trees, canopy cover, climatic conditions, and topographical conditions. Hence, classification of a forest into different stands or cohorts is an essential element of forest management, and age is the most common characteristic used to classify forests for management purposes. However, as stated earlier, in the multiple cohort approach of sustainable forest management, classification is done on the basis of compositional, structural, and age variables. Similarly, managers of national parks and wildlife sanctuaries use a forest stands/cohorts classification system based on a wildlife habitat suitability index. Hence, it is critical to consider the specific features of different cohorts/stands in forest harvesting decisions.

First, for simplicity reasons, we consider a forest of three types of stands or cohorts. In some cases of forest management, three cohorts may be enough, but in other cases a greater number of cohorts may be required. For example, the proponents of multi-cohort forest management (MCFM) in Ontario, Canada have classified forests in three cohorts: the first cohort of a young even-aged forest, the second cohort of a mid-successional forest, and the third cohort when virtually all the first cohort pioneer trees have died (Kuttner 2006). Generally, the number of cohorts/groups based on a wildlife habitat suitability index is more than three and varies across national parks.

Let us consider three types of forest stock/stands simply distinguished on the basis of age only—young, mature, and old stock. In terms of consumption, young stock is generally consumed for fuelwood, pole crop, and pulpwood, mature stock for agricultural equipments, small construction, and low-end furniture, and old stock for valuable construction and furniture. In terms of amenity values from forest stock, young stock provides wildlife habitat for small mammals, mature and old stocks provide recreation, wildlife-life habitat for big mammals, and existence values. The contributions of these three types of stocks to other values, such as carbon sequestration, watershed services, cultural values, are also not directly proportional to the volume of timber (cubic meters) in each age class. Hence, the utility, either from consumption or conservation, provided by a forest having a fixed growing stock, say 100 m^3 of wood, will depend not only upon the total timber stock, but also on the distribution of that timber stock in three classes of stock, and different types of forest stocks will have different utility functions for timber consumption as well as for amenity value from stock. Hence, the stocks and consumption from these three types of stands are not additive, whereas the utilities are additive.

In addition to the differentiation between the consumption and conservation utilities from different types of stocks, the dynamic relationship between the different types of stocks will also affect the economically optimal harvesting decisions. For example, with time the forest stock from the young class will move to the mature class and from the mature class to the old class, and this movement will influence the economically optimal conditions for harvesting and conservation. Hence, we propose a growth structure before we develop the EGGR for harvesting decisions.

We assume that the young forest stock is expressed as S_1, the mature forest stock as S_2 and the old forest stock as S_3. The proportions of these three forest stocks will vary from forest to forest, depending upon the biological features of each forest, natural disturbances, and forest management. The growth function of each stock is assumed to be logistic with S_1^*, S_2^*, and S_3^* as maximum possible stocks that can be preserved in the forest resource. As the forest resource grows, in a given period of time, some trees in the young stock remain in young stock and some cross over to mature forest stock. Similarly, within a given period, some trees in mature stock remain in mature stock and some cross over to old forest stock. The total growth of young forest stock is the difference between its own growth and its growth that crosses over to the mature forest stock; the total growth of mature forest stock is the sum of its own growth and the partial growth of young stock that crosses over to mature forest stock minus its growth that crosses over to the old forest stock; and the total growth of old forest stock is the sum of its own growth and the partial growth of mature stock that crosses over to old forest stock. If θ_1 is the proportion of the growth of S_1 that remains in S_1 and $(1 - \theta_1)$ is the proportion of the growth of S_1 that adds to the growth of S_2; and if θ_2 is the proportion of the growth of S_2 that remains in S_2 and $(1 - \theta_2)$ is the proportion of the growth of S_2 that adds to the growth of S_3, then the growth functions of the three stocks could be represented as:

$$R^1 = \theta_1 \rho_1 S_1 \left(1 - \frac{S_1}{S_1^*}\right) \qquad \text{where, } 0 < S_1 < S_1^* \tag{12.1}$$

$$R^2 = (1 - \theta_1)\rho_1 S_1\left(1 - \frac{S_1}{S_1^*}\right) + \theta_2\rho_2 S_2\left(1 - \frac{S_2}{S_2^*}\right) \qquad \text{where, } 0 < S_2 < S_2^* \quad (12.2)$$

$$R^3 = (1 - \theta_2)\rho_2 S_2\left(1 - \frac{S_2}{S_2^*}\right) + \rho_3 S_3\left(1 - \frac{S_3}{S_3^*}\right) \qquad \text{where, } 0 < S_3 < S_3^* \quad (12.3)$$

where, ρ_1, ρ_2 and ρ_3 are characteristic growth coefficients of young, mature and old stocks respectively. The values of ρ_1, ρ_2 and ρ_3 depend on the type of forest resource, and climatic, soil, and topographical features of the forest site.

12.3 The Enhanced Green Golden Rule

We modify the economic model of Chichilnisky et al. (1995) to incorporate three cohorts/stocks, and assume that the consumption and levels of three stocks contribute to utility. Suppose the utility function $U(C_{1t}, C_{2t}, C_{3t}, S_{1t}, S_{2t}, S_{3t})$ is strictly concave. For succinctness, we use the notation $U(C_t, S_t)$. We also assume that the utility function is additively separable in consumption and stocks. Suppose the production of man-made capital K_t occurs according to the linear homogeneous production function $F(K_t, S_{1t}, S_{2t}, S_{3t})$, and capital accumulation is expressed as

$$K_t = F(K_t, S_t) - C_t \quad (12.4)$$

The rates of change of the three stocks of forest are expressed as:

$$\dot{S}_{1t} = R^1 - C_{1t} \quad (12.5)$$

$$\dot{S}_{2t} = R^2 - C_{2t} \quad (12.6)$$

$$\dot{S}_{3t} = R^3 - C_{3t} \quad (12.7)$$

Similar to the GGR, in which society is concerned only with the long-run values of consumption and the levels of forest stocks, we seek a path to maximize the long-run utility, $\lim_{t\to\infty} U(C_t, S_t)$ The solution is specified by the following proposition:

12.3.1 Proposition

There exist values of $(K^*, S_1^*, S_2^*, S_3^*, C_1^*, C_2^*, C_3^*)$ characterized by

$$\frac{U_{s_1}}{U_{c_1}} = -R^1_{s_1} - \frac{U_{c_2}}{U_{c_1}} R^2_{s_1},$$

$$\frac{U_{s_2}}{U_{c_2}} = -R^2_{s_2} - \frac{U_{c_3}}{U_{c_2}} R^3_{s_2}, \text{ and}$$

$$\frac{U_{s_3}}{U_{c_3}} = -R^3_{s_3},$$

such that $\lim_{t\to\infty} U(K_t, C_t, S_t) = \mathrm{U}(K^*, S_1^*, S_2^*, S_3^*, C_1^*, C_2^*, C_3^*)$ is a necessary and sufficient condition for a feasible path (K_t, C_t, S_t) for all t to be a solution of the problem that maximizes $\lim_{t\to\infty} U(K_t, C_t, S_t)$ over all feasible paths.

Proof: The indefinitely maintainable values of C_1, C_2, C_3 and S_1, S_2, S_3 satisfy $R^1 = C_1$, $R^2 = C_2$, and $R^3 = C_3$. Therefore, the problem. Maximize $\lim_{t\to\infty} U(K_t, C_t, S_t)$, over feasible paths, reduces to Maximize $U(C, S)$

Subject to the constraints given by Eqs. (12.8), (12.9), and (12.10).

$$R^1 = C_1 \tag{12.8}$$

$$R^2 = C_2 \tag{12.9}$$

$$R^3 = C_3 \tag{12.10}$$

Similar to the GGR, the stock of capital is not a concern because any stock of capital can be accumulated over a sufficiently long period. The set of (S, C) satisfying the constraint in (12.8), (12.9), and (12.10) is compact, so this problem is well-defined. Hence, the maximum is characterized by the first order conditions:

$$\frac{U_{s_1}}{U_{c_1}} = -R^1_{s_1} - \frac{U_{c_2}}{U_{c_1}} R^2_{s_1} \tag{12.11}$$

$$\frac{U_{s_2}}{U_{c_2}} = -R^2_{s_2} - \frac{U_{c_3}}{U_{c_2}} R^3_{s_2} \tag{12.12}$$

$$\frac{U_{s_3}}{U_{c_3}} = -R^3_{s_3} \tag{12.13}$$

This completes the proof of Proposition 1.

We term the solution provided by Eqs. (12.11), (12.12), and (12.13) as the Enhanced Green Golden Rule (EGGR), and the rule provides the optimal conditions for three stocks. The rule does not provide the actual levels of harvesting but it tells that harvesting should be done in a way that these conditions are satisfied. The rule presented above is for a forest with three cohorts/stocks, but the similarity between the Eqs. (12.11) and (12.12) and the difference between the Eqs. (12.11) and (12.13) or (12.12) and (12.13) can be used to generalize the EGGR for any number of cohorts/stocks greater than three. On the basis of these three equations, we can conclude that the optimality conditions for all stocks, except the terminal stock, will be the same, while the optimality condition for the terminal stock will always be given by the equation that is the same as Eq. (12.13). Hence, a generalized EGGR for n number of stocks/cohorts is given by n equations given below:

$$\begin{aligned}
&\frac{U_{s_1}}{U_{c_1}} = -R_{s_1}^1 - \frac{U_{c_2}}{U_{c_1}} R_{s_1}^2 \\
&\frac{U_{s_2}}{U_{c_2}} = -R_{s_2}^2 - \frac{U_{c_3}}{U_{c_2}} R_{s_2}^3 \\
&\downarrow \\
&\downarrow \\
&\frac{U_{s_{n-1}}}{U_{c_{n-1}}} = -R_{s_{n-1}}^{n-1} - \frac{U_{c_n}}{U_{c_{n-1}}} R_{s_{n-1}}^n \\
&\frac{U_{s_n}}{U_{c_n}} = -R_{s_n}^n
\end{aligned}$$

12.3.2 Economic Interpretation of the EGGR

The optimality condition for the terminal stock (old stock) is the same as the optimality condition given by the GGR, that is, the optimality condition when stock differentiation is not considered. In addition, the optimality conditions for other stocks (young and mature stocks) will also turn into the same optimality condition as given by the GGR if the growth of stocks from one type of stock to another type of stock, such as growth from young to mature and mature to old stock, is assumed to be zero. In other words, if different forest stocks are considered independent of each other, the optimality conditions for different stocks will be the same as given by the GGR. Hence, the key distinguishing factor between the EGGR and the GGR is not the multiplicity of stocks, but the growth dynamics between different stocks. In the case of a forest comprised of n distinct stocks where each stock is defined in a way that the growth of all stocks always remains part of the same stock, we will get n conditions for optimality, but all of them will be the same as Eq. (12.13) or the same condition as for the GGR. In other words, in the case of a forest with n totally independent stocks, the GGR will be applicable to each stock separately.

Next, let us examine the differences between the optimality conditions for the terminal stock and all other stocks. The left-hand side (LHS) of each equation (optimal condition) signifies the marginal rate of substitution (MRS) between consumption and stock-level, and the right-hand side (RHS) corresponds to the marginal rate of transformation (MRT) of the respective stock. The EGGR gives the same optimality condition for the old (or terminal) stock (Eq. 12.13) as for the GGR; the MRS between consumption and stock-level is equal to the MRT of the stock with respect to itself. However, the optimality conditions for young and mature stocks (Eqs. 12.11 and 12.12) are different than the GGR conditions. For young stock, the EGGR requires that the MRS between the consumption and stock-level is equal to the MRT of the young stock with respect to itself plus the MRT of mature stock with respect to young stock expressed in terms of young stock (normalized by the ratio of the marginal utilities of mature stock and young stock). We call the RHS of Eq. (12.11) as the Normalized Composite Marginal Rate of Transformation (NCMRT) (composite of the rate of transformation of the young and mature stocks and normalized to express in the units of young stock). The same interpretation applies to all other stocks except the terminal stock. We would like to remind readers that the three Eqs. (12.11), (12.12), and (12.13) are not independent, and the optimal levels of three stocks will be given by the solution of these three simultaneous equations. Hence, readers should avoid inferences based on each equation independently.

12.3.3 Welfare Implications

The welfare implications of the optimal conditions for multiple stocks can be understood by expressing Eqs. (12.11), (12.12) and (12.13) as follows:

$$\Delta C_1 U_{c_1} = \Delta C_1 [U_{s_1} + U_{c_1} R^1_{s_1} + U_{c_2} R^2_{s_1}] \tag{12.14}$$

$$\Delta C_2 U_{c_2} = \Delta C_2 [U_{s_2} + U_{c_2} R^2_{s_2} + U_{c_3} R^3_{s_2}] \tag{12.15}$$

$$\Delta C_3 U_{c_3} = \Delta C_3 [U_{s_3} + U_{c_3} R^3_{s_3}] \tag{12.16}$$

These welfare equations describe the equalities, at the optimal conditions, between the welfare gain and welfare loss due to marginal changes in consumption or the level of stock, and not the overall welfare gain or loss due to a change in consumption or level of stock. As expected, due to the incorporation of multiple stocks and growth dynamics between different stocks, the welfare implications are quite different than the case of a single-stock-based GGR. The growth dynamics make these implications quite interesting because a decrease/increase in the consumption of a particular stock, say young stock, not only affects the level of that stock, but it also affects the growth of the same stock as well as of the next class of stock, the mature stock. Three terms on the RHS of Eqs. (12.14) and (12.15) capture the effects of change in the stock level and the growth dynamics of two groups of stock. In the case of terminal stock (old stock), since there is no movement of the stock from this class to the next class of stock, there are only two terms on the RHS of the equation (one for the level of stock and the second for the growth in this class of stock).

Using Eq. (12.14), let us analyze the welfare implications of reducing the consumption of young stock by an amount ΔC_1. The reduction in consumption will increase the stock S_1 by the same amount, and due to this change in the level of stock, the growth of S_1 and S_2 will be affected. The LHS of this equation, $\Delta C_1 U_{c_1}$, signifies the welfare loss associated with reduced consumption. The right-hand side of the equation gives the welfare increase due to the change in the level of stock equal to an amount ΔC_1 of the young stock. However, the welfare increase due to the change in the stock level is composed of three components: (1) welfare change of $\Delta C_1 U_{s_1}$ from increased level of young stock, (2) welfare change of $\Delta C_1 U_{c_1} R^1_{s_1}$ due to the change in growth of stock S_1 resulting from the increase of stock S_1, and (3) welfare change of $\Delta C_1 U_{c_2} R^2_{s_1}$ due to the change in growth of stock S_2 resulting from the increase of stock S_1. Similarly, Eq. (12.15) can be interpreted for a reduction in the consumption of mature stock by ΔC_2, and its welfare implications are the same as for the young stock. In the case of the terminal stock, Eq. (12.16), the loss in welfare due to the reduction in consumption by ΔC_3 is equal to the welfare gains due to the increased stock of S_3 and change in growth of stock S_3.

12.3.4 User Groups' Specific Optimal Conditions

One of the key features of the EGGR, similar to the GGR, is that the conditions for the highest indefinitely maintainable level of utility–which includes utilities from consumption as well as the stock of the forest resource–depends on the marginal utilities of consumption and level of stocks of different types of stocks (economic characteristics of the user groups of the respective forest) and the rate of growth of different stocks (biological features of forest under consideration). We call these conditions "conditions of sustainability" or "sustainable forest management". In these conditions of sustainability, there is no direct role for the price of timber and the discount rate, but the price of timber may depend on the marginal utilities of consumption of timber. Hence, the EGGR provides the sustainability conditions which may provide different levels of stocks and consumption levels of different types of stocks across different user groups due to the possible differences in marginal utilities of different stocks across user groups. This means that for the same type of forest (a forest which has the same biological features), the sustainability configuration (composition of different types of stocks) may be different in different locations depending on the marginal utilities of the associated user groups and, accordingly, harvesting decisions for sustainability will also vary across user groups as per their marginal utilities. Hence, the outcome of the EGGR may be a compositional diversity of the same types of forests which is in contravention to the idealistic concept of a normal forest—the same configuration of forests (all age classes) groups have the same area) across all user groups.

In addition, any user group's utilities, either from stock or consumption of different stocks, may not remain the same forever; the shape of the utility function may change or the values of utility indices may change over time, and that will lead to a change in the sustainability configuration of a forest over time. Hence, the sustainability conditions, given by the EGGR, are not static or a permanent equilibrium concept, but an evolutionary concept which captures the dynamics of economic as well as biological features. This is also contrary to the concept of a normal forest. The dynamics of sustainability conditions are similar to the concept of dynamics of optimal forest regimes proposed by Kant (2000).

12.4 An Illustration of the Enhanced Green Golden Rule

Let us assume that the utility function for a three-stock forest resource, introduced in Sect. 12.2, is a standard logarithmic Cobb Douglas function. Further, let us assume the index of the utility of stock S_1 is α, stock S_2 is β, stock S_3 is γ, consumption C_1 is $(1-\alpha)$, consumption C_2 is $(1-\beta)$, and consumption C_3 is $(1-\gamma)$. The utility function can be represented as:

$$U(C,S) = \alpha \ln S_1 + \beta \ln S_2 + \gamma \ln S_3 + (1-\alpha)\ln C_1 + (1-\beta)\ln C_2 + (1-\gamma)\ln C_3 \tag{12.17}$$

Using Eqs. (12.11), (12.12) and (12.13) and solving these equations, the EGGR gives optimum values for the consumption and levels of three stocks $(C_1,\ C_2,\ C_3,\ S_1,\ S_2,\ S_3)$ as follows:

$$C_1 = \theta_1 \rho_1 S_1 \left(1 - \frac{S_1}{S_1^*}\right) \tag{12.18}$$

$$C_2 = (1-\theta_1)\rho_1 S_1 \left(1 - \frac{S_1}{S_1^*}\right) + \theta_2 \rho_2 S_2 \left(1 - \frac{S_2}{S_2^*}\right) \tag{12.19}$$

$$C_3 = (1-\theta_2)\rho_2 S_2 \left(1 - \frac{S_2}{S_2^*}\right) + \rho_3 S_3 \left(1 - \frac{S_3}{S_3^*}\right) \tag{12.20}$$

$$\frac{\alpha C_1}{(1-\alpha)S_1} = -\theta_1\rho_1\left(1 - \frac{2S_1}{S_1^*}\right) - \frac{(1-\beta)C_1}{(1-\alpha)C_2}\left[(1-\theta_1)\rho_1\left(1 - \frac{2S_1}{S_1^*}\right)\right] \tag{12.21}$$

$$\frac{\beta C_2}{(1-\beta)S_2} = -\theta_2\rho_2\left(1 - \frac{2S_2}{S_2^*}\right) - \frac{(1-\gamma)C_2}{(1-\beta)C_3}\left[(1-\theta_2)\rho_2\left(1 - \frac{2S_2}{S_2^*}\right)\right] \tag{12.22}$$

$$\frac{\gamma C_3}{(1-\gamma)S_3} = -\rho_3\left(1 - \frac{2S_3}{S_3^*}\right) \tag{12.23}$$

In these six Eqs. (12.18–12.23), there are six unknowns (C_1, C_2, C_3, S_1, S_2, and S_3), that can be solved in terms of θ_1, θ_2, ρ_1, ρ_2, ρ_3, S_1^*, S_2^*, S_3^*, α, β, and γ. Here, for illustration purpose, we solve these equations for some assumed values of θ_1, θ_2, α, β, and γ.

Case 1: *A Forest Resource of Three Stocks in Which the Growth in Every Stock is Independent of the Other Stocks:* This means that all growth in the young stock remains in the same stock ($\theta_1 = 1$) and all growth in the mature stock remains within the mature stock ($\theta_2 = 1$).

Substituting $\theta_1 = 1, \theta_2 = 1$ in Eqs. (12.18–12.23) and solving, we obtain

$$S_1 = \frac{S_1^*}{[2 - \alpha]} \tag{12.24}$$

$$S_2 = \frac{S_2^*}{[2 - \beta]} \tag{12.25}$$

$$S_3 = \frac{S_3^*}{[2 - \gamma]} \tag{12.26}$$

These three equations clearly indicate that the optimal level of each type of stock (young, mature, and old) depends on the possible maximum level of that stock (S_1^*, S_2^*, and S_3^*) and the utility index (α, β, γ) for the level of that stock. As the utility index for the level of stock increases, the optimal level of the stock also increases. The maximum possible value of the utility index is 1 which means that forest user groups derive all utility from the level of stock and no utility from the consumption of that stock; in such cases, the optimum level of stock will be equal to the possible maximum level of the stock. On other hand, if user groups derive utility only from consumption and no utility from the level of stock, the utility index for the level of stock will be equal to zero, and in this case the optimal level of stock will be half of the possible maximum stock. Given our growth functions for the three types of stocks, the Maximum Sustained Yield (MSY) levels for young, mature, and old stocks are 0.5 S_1^*, 0.5 S_2^*, and 0.5 S_3^*, respectively. Hence, in the case of no utility from the level of stocks, the optimal solution will be equal to the MSY for all three stocks. However, if user groups derive any utility from the levels of stocks ($\alpha > 0$, $\beta > 0$, $\gamma > 0$), the optimal stock levels will be higher than the MSY levels of the stocks.

In essence, if we consider a forest composed of different stocks, but that all stocks are independent of each other (there is no movement from one type of stock to other types of stocks), the optimal level of each stock will depend on the utility index of the level of that stock (user groups' characteristic) and a biological characteristic of the forest—the possible maximum level of that stock. In the case of some societies, such as Aboriginal groups and other tribal groups, utility indices from the levels of stocks may be close to 1 and utility indices from the consumption of all stocks close to zero. In this case, the optimum level of all stocks will be the possible maximum levels of stocks, which means conserving all stocks and letting them reach the possible maximum levels. In the case of industrial-growth focused societies, utility indices from the consumption of all stocks may be close to one while the utility indices from the level of stocks may be close to zero. The optimum level of stocks in these cases will be equal to the MSY of each stock.

These are two extreme cases. In other cases, the optimum levels of stocks will be somewhere between the possible maximum level of each stock and the MSY of respective stock.

Case 2: *A Forest Resource of Three Stocks in Which All Growth in Young Stock Crosses Over to the Mature Stock* ($\theta_1 = 0$) *and All Growth in Mature Stock Crosses Over to the Old Stock* ($\theta_2 = 0$).

Substituting $\theta_1 = 0, \theta_2 = 0$ in Eqs. (12.18–12.23) and solving, we obtain

$$C_1 = 0$$

$$C_2 = \rho_1 S_1 \left(1 - \frac{S_1}{S_1^*}\right)$$

$$C_3 = \rho_2 S_2 \left(1 - \frac{S_2}{S_2^*}\right) + \rho_3 S_3 \left(1 - \frac{S_3}{S_3^*}\right)$$

$$\frac{\alpha}{S_1} = -\frac{(1-\beta)}{C_2}\left[\rho_1\left(1 - \frac{2S_1}{S_1^*}\right)\right]$$

$$\frac{\beta}{S_2} = -\frac{(1-\gamma)}{C_3}\left[\rho_2\left(1 - \frac{2S_2}{S_2^*}\right)\right]$$

$$\frac{\gamma C_3}{(1-\gamma)S_3} = -\rho_3\left(1 - \frac{2S_3}{S_3^*}\right)$$

These six equations can be solved for C_1, C_2, C_3, S_1, S_2, and S_3 only if we know the values of ρ_1, ρ_2, ρ_3, S_1^*, S_2^*, S_3^*, α, β, and γ. Hence, for illustration, we assume that the growth coefficients for all three stocks are equal to unity ($\rho_1 = \rho_2 = \rho_3 = 1$), and utility indices for the level of stocks for all three stocks is equal to 0.5 ($\alpha = \beta = \gamma = 0.5$). This means that the utility indices for the consumption of all three stocks are also equal to 0.5. In other words, this is the case in which elasticity of utility with respect to consumption and the level of stock are the same (0.5) for all three types of stocks. Using these values, we get the following solutions:

$$S_1 = \frac{2S_1^*}{3} \tag{12.27}$$

$$S_2 = \frac{3S_2^*}{4} \tag{12.28}$$

$$S_3 = \frac{3S_3^*}{4} \tag{12.29}$$

Equations (12.27), (12.28), and (12.29) provide the optimal levels of stocks for young, mature, and old stocks, respectively, and the optimal levels for all three stocks are greater than the respective levels of stocks for the MSY. The optimum level of young stock is only two-thirds of the possible maximum level of this stock, while the optimum levels of mature and old stocks are three-quarters of their possible maximum levels. This may seem strange but it is due to the fact that all growth in the young stock moves to the mature stock which results in no consumption of the young stock even though there is a positive utility from the consumption of young stock. Hence, this is an outcome of our assumption which we have to make to find a solution in the simplest way.

In brief, we can conclude that the optimal levels of different stocks will vary between the MSY levels of the stocks and the maximum possible stocks, while the actual level of an optimal stock will depend upon the utility indices of the levels of stocks and growth functions of different stocks. For any specific stock, the optimal level of that stock will be closer to the MSY level for a low utility index of the level of stock and a higher utility index for the consumption of that stock; while the optimal level of that stock will be closer to the possible maximum level of that stock for a high utility index of the level of stock and a low utility index for the consumption of that stock. We can obtain optimum levels of conservation of these stocks for different combinations of θ_1 and θ_2 depending on the type of forest.

12.5 Conclusions

The concept of the Green Golden Rule, introduced by Chichilnisky et al. (1995), gives a path of maximum sustainable long-run utility, accounts for future generations in determining the optimal solutions, and includes utilities from resource consumption as well as the level of resource stock or amenity values of the resource. The concept of GGR is much closer to the requirements of sustainable forest management as compared to the concept of the normal forest used by the Faustmann forest economist to determine harvesting decisions for a forest. Hence, in this chapter, we extended the concept of GGR to incorporate the diversity of forest stocks, and identified the optimal conditions for a forest of three types of stocks as well as a forest of n types of stocks, and illustrated the determination of optimal conditions using the Cobb-Douglas Utility function and logistic growth function of forest stocks. The results of this chapter provide many useful insights with respect to harvesting decisions for sustainable forest management.

The most significant result of this chapter is that the harvesting decisions for forests for sustainable forest management will not be the same across different user groups even for forests that are biologically same. Harvesting decisions will be affected by the user groups' utilities from consumption as well as the amenity values from the level of stocks (conservation of stock). User groups' utilities will vary across groups, and therefore harvesting decisions will vary across user groups. The variation in user groups' utilities also imply that the sustainability composition of the same type of forests will be different across user groups, and that means the concept of the normal forest is redundant. Hence, Post-Faustmann forest economics has to have its roots in the concept of multiple and evolving equilibria rather than in the concept of a single and permanent equilibrium such as a normal forest.

Second, the EGGR does not provide harvesting rules but it does provide the levels of different stocks that need to be conserved for maximum long-run sustainable utility. Hence, the harvesting rules have to be designed by forest managers according to the levels of stocks to be conserved. This is similar to current forest management practices in which forest managers design harvesting rules considering only the biological aspects of forests. However, sustainability includes ecological, social, and economic considerations, and therefore the inclusion of social and economic dimensions in forest harvesting decisions is critical. The outcomes of the EGGR provide a tool to forest managers to develop harvesting rules that incorporate different user groups' consumption preferences as well as their preferences for amenity values.

Third, the inclusion of multiple stocks or cohorts extends the application of the Green Golden Rule to all types of forest management, such as management for biodiversity, wildlife habitat management, near-natural forest management, continuous cover forest management, Aboriginal forest management and even forest management for industrial purposes only. Hence, the EGGR can be used to design harvesting rules for any type of forest management.

Finally, good knowledge of user groups' utilities and the growth functions of each stock of different types of forests is essential for the applications of the EGGR. Hence, for sustainable forest management, all agencies involved in forest management should focus their attention on studies of forest growth and user groups utilities.

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Chapter 13
Land Expectation Value to Profit Maximization: Re-Examination of the Faustmann Formula

Yaoqi Zhang and Suman Majumdar

Abstract By comparing the use of land expectation value (LEV), internal rate of return (IRR), labor wage expectation value (WEV), and profit in finding optimum rotation age in forest management, it is argued that the four approaches are essentially similar in maximizing the residual value but different in sharing the value from production. In the long run, the residual (loss) is created by all four factors and are shared depending on relative factor markets. Profit maximization is the most general approach as the scale of land, capital, labor and time are considered. If time value of capital becomes more costly, more land will be applied to substitute the time (shortening rotation); if land becomes more costly, longer rotation will be applied to substitute the land (shrinking land holding). If labor is more costly, more land and longer rotation will be applied. Considering the fact that timberland market is becoming active, and the role of entrepreneurs and investors who pay more attention to the scale of land than the rotation issue in land management, LEV approach which treats the scale of land as fixed is no longer appropriate. This chapter argues that profit maximization would be a more general and suitable approach as it can incorporate both scale of land and capital (management input) and time simultaneously.

Keywords Faustmann · Forest land markets · Forest rotation · Internal rate of return · Land expectation value · Profit function · Rent · Timber investment management organizations · Wage expectation value · United States

Y. Zhang (✉)
School of Forestry and Wildlife Sciences, Auburn University, 3213 SFWS Building,
602 Duncan Drive, Auburn, AL 36849-5418, USA
e-mail: zhangy3@auburn.edu

S. Majumdar
Center for Government and Public Affairs, Auburn University Montgomery,
400 S. Union Street, Montgomery, AL 36104, USA
e-mail: suman.majumdar@cgov.aum.edu

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13.1 Introduction

Determining optimal rotation age is one of the oldest and most important problems in forestry (Pearse 1967). This problem has been investigated from different perspectives at different times. Maximum sustainable yield (MSY), net present value of one rotation (forest rent) (von Thunen 1826), land expectation value (LEV) (Faustmann 1849), and internal rate of return (IRR) (Boulding 1935) are all well-known approaches. LEV was first proposed by Faustmann (1849) and further developed by Pressler (1860) and Ohlin (1921). Gaffney (1957) made an early reference to LEV in English, followed by Bentley and Teeguarden (1965) and Pearse (1967). Faustmann's paper was translated into English in 1968. The popularity of LEV is largely due to Samuelson (1976), who argued that the LEV maximization was the only correct method for finding optimal rotation age. Since the publication of Samuelson's article, the LEV maximization approach has profoundly influenced the forest economics literature, and has become the golden rule and corner stone of forest economics (Newman 2002).

Brazee (2001) claimed that Faustmann's work was relatively vague for more than 100 years. We speculate that the negligence was due to the unavailability of good growth and yield models, and small efficiency gain from the LEV approach over other methods (e.g., one rotation model, and MSY). We know the gain in using LEV over MSY is from positive interest rate, and over forest rent from inclusion of land cost. If inflation of timber price is close to interest rate in a long term and if the cost of annual rental value for long rotation forest management is minimal (especially when land is abundant and land used in forestry is mostly marginal land), the three approaches might lead to similar results. Therefore, although LEV was originally developed in Germany, practical forestry in Germany is nowadays guided by silvicultural and ecological models that aim to guarantee sustainability instead of ensuring economic efficiency (Mohring 2001). In Finland, where LEV has been well studied and is popular, it is widely believed, even in official silvicultural guidelines (Hyytiaiene and Tahvonen 2003), that the MSY and forest rent value approaches are close to the LEV approach. Even in Canada, which is a capitalist country, forest rotation decisions are based on MSY or other silvicultural requirements, and not on LEV. In China, MSY has been used as the principle of forest management; LEV has just received attention in academics recently. Similarly, most of the forest harvesting decisions by non-industrial private woodlot owners in developing and developed countries like Canada and the USA are made on the basis of factors other than the LEV maximization. For example, trees would be cut when the owners feel they are biologically mature and, more often, when cash or wood is needed, such as for a wedding, building or repairing home, and sending kids to school.

There is no doubt that Faustmann's calculation of the LEV of a forestland was correct, but it is hard to believe that Faustmann's intention was to prescribe the optimal economic forest rotation based on the LEV maximization. Hence, the full credit for the popularization of forest rotation based on the LEV maximization and the current state of forest economics, which is heavily dominated by Faustmann's formulation, goes to Samuelson (1976). Samuelson's paper might have been a good catalyst for the growth of forest economics, and there was nothing wrong in demonstrating that the LEV formulation was the correct method for determining optimal forest rotation if all the assumptions necessary for the formulation were met. However, the outright rejection of other methods for determining forest rotation, specifically the IRR, the MSY, and the forest rent, appears to be an example of economic arrogance rather than of critical economic thinking. Samuelson (1976) totally neglected Bentley and Teeguarden (1965), in which the authors compared many methods of forest rotation and associated assumptions, illustrated the relationships between various forest rotation methods through a generalized approach, and resolved the logical inconsistencies between the present net worth and the IRR methods. Samuelson, to his credit, did an extensive search of forest economics literature, and there were references in his paper which were hardly cited anywhere else. Hence non-inclusion of Bentley and Teeguarden (1965), which was published in the top American journal of forestry—Forest Science, is a mystery. Moreover, this might have caused a great loss for the forest economics literature because if Samuelson included Bentley and Teeguarden (1965) in his discussion, his paper (Samuelson 1976) could have been quite different.

Our main focus is on how to manage forest when land market, like capital and labor market, emerges. A rational behavior will not just try to maximize land value from the land already held under forest by optimizing rotation only, but will also optimize the land holding size. Land is a variable input factor like labor and capital, and the unit cost of land is the market price (or rental price). The objective is to maximize profit, when rotation is also interactive with land variable. It is likely that more land will be applied to substitute time (that is, shorten rotation) if interest rate becomes higher; on the other hand, longer rotation will be applied to substitute land if land becomes more costly.

Some people might argue that land value can be obtained by the LEV approach instead of using land market price. While LEV is one of the approaches, but it is more problematic: first, it is well known that LEV does a very poor job in estimating land value since we do not know too many things about the future; second, if the land value based on LEV of management is higher than the market price, the difference is not from land but from better skills of managing the land. In other words, the gap is value of management skills. One should buy more land until the marginal value of land in production is equal to the market price.

We all know very well, specifically economists and forest economists, that the concept of perfect market is just a fiction and good for comparing the actual markets, but there is no market which satisfies all the necessary conditions of the perfect market. Hence, it is economically rational that different private forest owners harvest their forests using different rotation ages as per their own personal preferences concerning consumption outlays of different dates. However, the proponents of the LEV formulation are not willing to accept that. It is true that Samuelson (1976) only referred to this specific context, imperfections in capital markets, and the literature in the past 35 years have addressed many such issues like imperfect markets and market uncertainty. In general, with respect to optimal forest rotation, forest economists have been concerned only about the conditions of the market and some natural uncertainties like forest fires and insect breaks, but have neglected the context in broader sense, such as changing forest property rights, emerging forestland markets, and the entry of modern entrepreneurs in forestland markets.

In this chapter, we argue that the LEV formulation is a special case of profit maximization, and that other special cases of profit maximization are the IRR and the wage expectation value (WEV). If land is fixed, but labor and time are variable, LEV is the appropriate approach; if labor is fixed, and land and time are variable, it is WEV; and if capital is fixed, but labor and land are variable, it is IRR. In some situations, even any of these three methods (LEV, IRR, and WEV) may be inappropriate, and the application of profit maximization will be appropriate. In some sense, we are following Bentley and Teeguarden (1965), and extending his arguments to other methods of determining forest rotation and the current state of forests.

In this chapter, we first discuss economic concepts of rent, wage, interest, and profit maximization. Second, we provide some examples of recent developments related to changes in forestland markets. Third, we discuss the concepts of entrepreneurship and profit maximization. Finally, we conclude with some implications for other situations.

13.2 Rent, Wage, Interest, and Profit in the Marketplace

In classical economic theory there are primarily three different factors of production: land, labor, and capital. The return to land is rent, to labor wage, and to capital profits (Smith 1776; Landreth and Colander 1989). The IRR approach proposed by Boulding (1935) is the discount rate that makes the present value of total profit equal to zero. IRR is essentially the compound ratio of annual net return to capital. Boulding's theory of IRR maximizes the value of capital measured by compound annual return (or discounted all future return). Boulding (1935) did not include rent in his analysis most likely because the cost of timber land at that time was too small to get his attention. The IRR and LEV approaches are quite similar, both being simply maximizing the residual value for capital and land, respectively. The most serious problem with IRR is that it does not consider the scale issue of inputs (quantity of saplings in Boulding's example), while the problem with LEV is that it does not consider the scale issue of land.

LEV is a measure of discounted all future net value from a given land. LEV is estimated by maximizing the value of land after the costs of other factors, while IRR is estimated by maximizing the value of capital. IRR and LEV correctly measure annual return (or present value of perpetual return) for capital and land, respectively, but do not address the scale issue of capital and land, respectively.

LEV is a land-focused approach, while the IRR is a capital-focused approach. Considering the fact that the cost of capital is generally more available and value of land is usually less changeable, the LEV approach appears to be more convenient and superior. Of course, IRR might lead to multiple solutions, but that is only in some very special cases and usually would not happen in forestry in which large investment occurs in the beginning and revenue is obtained at the end of rotation. Another difference is that IRR is a ratio and LEV is a residual value. But if the capital value (denominator) is given, maximizing the ratio is same as maximizing the annual net revenue (numerator).

Similar to land and capital, labor is also one of the three factors of production, and it also needs to be considered in determining optimal forest rotation. It may be reasonable in case of natural forests to assume cost of labor to be negligible, or fixed at the beginning of the rotation, but labor cost cannot be neglected for intensive forest management and industrial plantations. In the case of agriculture, agricultural economists have used (annual) *wage maximization* for a tenant farmer as the criterion for determining the optimal level of inputs. In tenancy, there can be different types of contracts. Tenants can make payments to the owner either of a fixed portion of the product, in cash or in a combination of cash and product. Suppose tenants do not hire additional labor from the market, then the annual wages are essentially the residual values after annual rent. In agricultural land management there is (was) abundant evidence of wage maximization. The level of rent would be important for a tenant to make decisions, such as how big of a land to manage and how intensely. The rent is often determined by demand and supply of land and labor in the market. Individual farmers are rent takers as they are not very powerful in negotiating rent. It is true that the result is same whether a farmer maximizes rent or wage, but conceptually a farmer maximizes wage and not rent. Sometime the wage and rent are integrated together. Under the forest shareholding systems in China, labor inputs are measured by shares similar to the share of land (Song et al. 1997; Zhang 2001), and labors are paid at the harvesting time to claim the share of residuals, like rents.

Profit is net revenue after paying for the costs of land, labor, and capital. The entrepreneur maximizes the firm's profit by accessing markets of inputs and outputs. Like landlord, the entrepreneur would maximize his *annual* profit (equivalent annul income) or *perpetual value* of the firm (equivalent to market value of the firm), not the net present value received from one rotation. By the term "profit" the classical economists meant profit and interest. Classical economists failed to distinguish between profit and interest because a typical firm of that time combined the roles of the capitalist and the entrepreneur. Similar to the classical approach of profit, the LEV approach fails to distinguish between land rent and profit. Total residual value is land rent if we assume no profit.

J. B. Clark, an early developer of marginal productivity theory, recognized that the return to the entrepreneur for management services is not profit, but wage (Landreth and Colander 1989). Similarly, classical economists recognized that the income of the capitalist entrepreneur consisted of three different elements; a payment for use of capital, a payment for management services, and a payment for

Table 13.1 A comparative analysis of the IRR, LEV, WEV, and profit maximization

	LEV	WEV	IRR	Profit maximization
Objective	Land value	Wage (labor) value	Capital value	Firm value
Who	Land owners/ managers	Fixed-rent tenant farmers (peasants)	Capital owners/ managers	Entrepreneur, investors, firm managers
Method	Fixed land, residual value going to land owners	Fixed labor, residual value going to farmers	Fixed capital input, residual value going to capital owners	Variable labor, capital and land, residual value going to entrepreneur
When	Land market was not active, and transaction costs are high, and land use is static	Labor market was not active, and rent was well-known to all people	Capital market is not active; transaction costs for capital are very high	Both land and capital markets are active; land uses are heterogeneous, and labor market is competitive
Time	Before the 1900s	Around the 1900s	1900s to 1960s	After 1960s

the risks of business activity. When the market of any input factor is perfect, there is no place for entrepreneurs. All residual value beyond the costs of other factors would be received by the owners of the firm in the imperfect market. This rent is very close to the entrepreneurial rent or Schumpeterian rents which have been further described in Collis and Montgomery (2005).

From the discussion above we can see that the IRR, LEV and WEV are all special cases of profit maximization. Profit maximization is a more general approach that includes all factors of production and their costs (rent, wage and interest) and determines the optimal levels of the use of all factors. Hence, there is no implicit assumption in the profit maximization about the scale of land, labor or capital. The different approaches have their own socio-economic context. Table 13.1 further explains the fundamental differences in these approaches.

13.3 Emerging Forestland Markets

Faustmann's paper appeared in 1849, and it is a common understanding that in the 19th century forestland markets were non-existent or at least not well developed. Hence, Faustmann's paper was a great contribution to forestland value calculation when market prices of land were not available. Its practical application was to estimate land value for taxation purpose. Samuelson (1976) listed one of the four assumptions as the existence of perfect forestland markets. If forestland market is perfect, forestland value would be available from the market and we would not need the Faustmann formula. In the presence of perfect forestland markets, why the optimal forest rotation decision has to be based on the implicit value of forestland, calculated from the LEV formulation, and not on the actual market value of forestland?

The need for LEV approach is strongly related with the absence of land market. Needless to say since 1849, even since 1976, the traditional picture of landownership and land market has been changing tremendously. Land has been becoming a more common object of trade and land price has become readily available from the market exchanges.

Using the United States as example, the biggest change in forestry had been the decline in ownership by farmers and the rise of forestland ownership by individuals outside of traditional farming and forestry operations from the 1960s to 1980s. Another significant change has been the emergence of institutional timberland investors since the 1980s. Institutions often hire Timber Investment Management Organizations (TIMOs) to buy, manage and sell timberlands on their behalf. The TIMOs have largely acted as fiduciaries for using timberland as an investment instrument (Clutter et al. 2005). Institutional investors can also go through with Real Estate Investment Trusts (REITs) in timberland investment. REITs are special tax designations for corporations investing in timberland real estate that reduces or eliminates corporate income taxes. In return, REITs are required to distribute 90 % of their income back to the investors. Like other corporations, REITs can be publicly traded or privately held. Public REITs, such as Plum Creek and Rayonier, may be listed on public stock exchanges.

More than 40 million acres of U.S. timberland have shifted ownership to TIMOs and REITS. In 2000, forest products companies owned approximately 20 % of privately owned US timberland, of which 36 million acres was in the US South. By the end of 2010 much of these Southern US timberland holdings had changed hands, some more than once, and most of the rest had moved to different ownership structures (Harris et al. 2011). Institutional timberland investments were started in the USA, but rapidly expanding to other regions. According to DANA Ltd. & HTRG Research, about 91 % of the investment by institutions is in the USA, 2 % in the South America, 5 % in Australia and New Zealand, and 2 % in other areas (Hagler 2006). Institutional investment in New Zealand accounts for nearly 4 % of world total and exceeds forest industry holdings (Hagler 2006).

The massive scale of industry-owned timberland sales into institutional investors is the best example of an active timberland market and emerging new players (entrepreneurs) in forestry sector. While the main reasons behind these changes are to take the maximum advantage from the existing and revised tax laws, and not necessarily to increase the economic returns by enhancing forest management practices or improving forest productivity, current timberland management is strong evidence of asset management era. Value can be added to the investors through opportunistic acquisition or transaction size. Managers of TIMOs and REITs behave more like capital or asset owners than land owners. Their most important objective is to increase asset market value.

13.4 Entrepreneurship and Schumpeterian Rents

Profits accrue if the total revenue of the firm exceeds the total costs of inputs. According to J. B. Clark, perfectly competitive markets would result in zero rate of profit in the long run (Landreth and Colander 1989). Clark explained profits in perfectly competitive markets only as the result of disequilibrium occurring when the firm moves to a new position of long run equilibrium. The concept of entrepreneurs and the profit theory almost disappeared in the neoclassical economic theory because of the assumption of perfect information (Obrinsky 1983). Perfect foresight and/or instantaneous adjustments leave no role for an entrepreneur. Frank H. Knight argued that perfect competition would not necessarily eliminate profits (Landreth and Colander 1989). Distinguishing between risk, which is insurable, and uncertainty, which is not, Knight argued that even in long-run equilibrium, entrepreneurs would earn profits as a return for their bearing with uncertainty.

Joseph A. Schumpeter took a different approach to profit theory, emphasizing the role of innovation. According to Schumpeter the function of the entrepreneur is differentiable from that of capitalist, landowner, laborer, or inventor (Ekelund and Hébert 1997). The entrepreneur can be any or all of these types of people only by coincidence rather than by functional nature. The function of entrepreneur, in principle, is not connected with possession of wealth, although possession of wealth by chance is an advantage for the entrepreneur. In practice, however, the basic function of an entrepreneur is almost always mixed with other economic activities. But management is not a distinctive role of an entrepreneur. Making decisions can be a function of the entrepreneur, however. According to Schumpeter, the dynamic entrepreneur is the person who makes innovations and "new combinations" by such things as introducing new products or processes, identifying new export markets or sources of supply, or creating new types of organization.

We see an entrepreneur as someone who organizes, makes innovations and new combinations, buys and sells land, or uses the land alternatively, or assumes the risk of a business in return for profits, or simply foresees the change in LEV. It can be mixed with other economic roles, such as landowner, capitalist, or laborer. Profits, thus, is a combination of returns to managerial activities and returns to innovations and taking uninsurable risks. The entrepreneur employs land, labor, and capital in the production process and makes payments to them according to their marginal productivities. The profits can be entrepreneurial rent or Schumpeterian rents. While Schumpeterian rents are generally used for technological innovation and earned by innovators, they can perfectly be applied to the case of innovative land management, such as higher and better uses not been known by other people.

In a perfectly competitive situation, profits would be zero in the long run, but it can never be zero at any specific time. The fundamental cause of existence of entrepreneurs is the less perfect market of labor, capital and land. In a more dynamic society, for example, rapidly rising population, changing technology and economy, land value is more likely to be variable; therefore the variation of ability to capture residual value among different people is larger. With such a variation, land is constantly moving to people who can make better and higher value uses. One example is the urban–rural interfaces where land used for timber production is much less valuable than development. Since developers are more capable to capture the value, it is naturally the traditional timberland owners who are selling their land to developers at such locations. Another example is the growing non-timber production value of timberland, such as aesthetics and recreation, bioenergy, carbon credit, and environmental easement. Due to rapidly changing land use, different individuals have different perspectives (information) of the future land value, and capability to capture the value.

13.5 Conclusions

LEV has served as the foundation of the economic theory of optimal rotation for timber production. The most important aspect of the LEV approach is examining the land value from annul or perpetual perspective. There are many limitations of the LEV approach, and a large number of studies have addressed some of these limitations. However, the issue of the scale of inputs, specifically size of land, has not been addressed. In addition, the value of trees is created jointly by land, labor and other inputs, but LEV claims all residual value to land after paying for labor and other costs. This neglects the issue of allocating residual value among all factors of production (land, labor, and capital), and this issue has also not attracted the attention of forest economists. In other words, the role of entrepreneurship in forest management has been totally neglected. These issues have gained increased importance due to changes in forestland markets in the last few decades. Hence, the application of LEV needs to be re-examined in the context of the changing forestland market conditions.

In the long run, prices of all the factors are expected to be endogenous instead of exogenously given. The return (or profit, or price) to the entrepreneur is also an endogenous variable. Since timberland, labor and capital owners, and entrepreneur evaluate their own value against market value in the competitive markets and adjust prices accordingly, any rise of return would cause the cost of other factors. Given the forestland market conditions, profit maximization is more capable of considering both optimal rotation and optimal holding problems.

In theory, forest economics is still under the immense influence of the Faustmann Formula: landowner maximizes the value of her fixed area of land by choosing the optimal rotation age and application of other variable inputs. This chapter argues that today there is a need of, and in fact there is existence of, entrepreneurs who maximize profit by choosing the rotation age and other variable inputs including land. Land is treated as a variable, same as labor and capital, in profit maximization as land market emerges. When forestland markets are working efficiently, at least as efficiently as labor and capital markets, there is no economically justifiable reason to treat land input to forest production differently than the inputs of labor and capital. Fundamentally the limitation of LEV is exactly same as the limitation of IRR and WEV approach. Essentially, all three approaches are maximization of the residual value after the costs of another two factors. Only profit maximization treats the three factors in same way, and represents the general situation of current circumstances of the markets.

In the presence of forestland markets, the decision of when to buy (expand) or sell timberland is as important, if not more, as the decision of when to harvest trees. In these situations, the land under current management is constantly assessed by the owner against market price resulting from market trading. If LEV calculated by the owner is less than the market price, the best strategy would be to sell the timberland, and vice versa. In other words, the opportunity costs of land are available and can be included in the calculations for maximizing profit. The marginal return to the land managed by each person diminishes; the optimal holding size is attained when the marginal revenue of land is equal to the land market price rather than the annual cost calculated by LEV which is endogenously determined. When LEV is larger than market price, a lot can be gained by adding more land, and vice versa. Hence, in the presence of forestland markets, profit maximization, and not LEV, will provide economically sound answers.

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