FOREST ECONOMICS: GIVING CONTENT TO THE RELATIONSHIP BETWEEN FORESTS AND SOCIETIES

Jussi Uusivuori
Finnish Forest Research Institute Metla, Finland

Keywords: applied economics, deforestation, dynamic models, econometrics, economic optimization, economic policies, externalities, market equilibria, market failure, land ownership, policy failure, public goods, private goods

Contents

Summary

This chapter covers forest economics as a scientific discipline in a nutshell. The text draws heavily on the author’s experience as a researcher for over a quarter of a century, and on his long-time collaboration and contacts with academic colleagues worldwide. The topics and themes dealt with in the chapter are selected to give an accurate and sufficiently comprehensive account of questions that are of interest in the discipline. Attention is given to examples and contexts from the forest sector that are open to economic analysis. To some extent – but not entirely – the structure of the text is based on the economic motivation of policies that influence agents and institutions in the forest sector and on the nature and character of goods and services emanating from forests. Forest economics extracts information from the relationship between forests and societies and strives to give content to this relationship. Within the large realm of economics, forest economics is a small subfield. However, after reading through this text, the reader may agree with the author’s conviction that the field is a very rich discipline. Not surprisingly, forest economics is known to inspire researchers throughout their careers.

1. General Introduction

Forest economics is a subfield of economics studying topics related and relevant to the forest sector. The forest sector covers forests, woods, landscapes with trees, products and services emanating from forests, related markets, forest conservation, as well as institutions and policies that govern the ownership, management and use of forests.

As the field itself has an extensive coverage of the sector-specific topics, the issues of interest for the discipline vary substantially both in scope and scale. Thus, forest economists may be interested in – but not limited to – researching optimal combinations of forest management methods within a specific type of geographic and environmental context, underlying causes of land use changes, the role of exchange rates in the international trade of forest products, competition conditions on timber markets or the corrective policies to ensure a socially optimal amount of environmental benefits from forests. While in scope and scale, the problems tackled in forest economics may have only a little in common with each other, they all share an underlying economic character in the sense that economic thought is a meaningful starting point and context in which to approach them.

Various branches of economics are present in forest economics research. Work done in the field may apply microeconomics, macroeconomics, welfare economics, development economics, industrial economics, or environmental and ecological economics. The work in forest economics may be theoretical or empirical, and common methods are theoretical, numerical or econometric modeling. Data-based models vary in the extent and detail level of the data used. The most specific models can be very detailed ones, utilizing a wide-array of data on plant growth and other data.

Of special interest is defining the relation of forest economics with respect to environmental, resource and ecological economics. Based on the above description, forest economics draws heavily on several fields of economic thought. Thus, forest economics should not be seen as a subdiscipline of environmental economics or resource economics alone, although an important part of forest economics research does fall under these subfields of economics. This part of forest economics can be referred to as environmental economics of forests, or forest resource economics. Yet, another subfield of forest economics could be referred to as ecological economics of forests (or forestry), which focuses on the interdependence and co-evolution of forest ecosystems and economic systems, and which holds on to a normative approach to enhance sustainability in natural and economic systems, where the economic systems are regarded as part of the natural systems.

It should be pointed out, however, that forest economics, as a scientific field, precedes most branches of economics. Its origins go back to the early 1800s, when the economic value of timber and forestland as investments were first given some systematic consideration. The paradigm of sustainable forestry developed at that time as well. Sustainability was understood in terms of forests' continued capacity to produce timber.

Currently, there are several factors contributing to the increasing demand for the knowledge offered by forest economic research. The value of forests as ecosystems and as usable resources is growing and better recognized, as forest resources in many locations are shrinking or threatened. Forests' and forest products' role in mitigating climate change is also recognized in the international climate regimes. Additionally, as the nonrenewable sources for materials and energy become scarcer and harder to tap, and as fossil energy and material sources continue to pollute the climate, forests and forestry are increasingly valued as a renewable resource sector. At the same time, there are likely changes in the industrial uses of forests. For example, demand for paper is weakening in developed markets, while demand for certain chemical substances produced from wood is growing. Many societies are also recognizing recreational values from forests and associated wellbeing. Forest economics, as a discipline, can offer valuable insights to policy makers and practitioners in designing better ways to address the relationship between human welfare and forest ecosystems.

In what follows, questions and phenomena that are of interest in forest economic research are covered. These are themes and topics that the field sheds light on and provides solutions for related problems.

2. A Fundamental Issue: How to Allocate Forest Resources

2.1. Allocation to Which End?

A fundamental question in economics is that of the optimal allocation of scarce resources between competing ends. This is also a very basic and fundamental question in forest economics: what is the best way of dividing forest resources between different uses. This allocation problem can take the form of dividing a piece of forestland between tree species, age-classes, size-classes, types of forest management or between conservation and timber production. But it can also take the form of dividing forest biomass resources between different end-uses, e.g., between energy wood, wood for industrial materials, woody biomass for soil fertilization, or wood in standing trees.

One can also think of other types of allocation contexts with respect to forest resources, such as determining the shares of forestland between publicly owned governmental forests, community forests, and private family forests or private industrially owned forests. Another type of division is that between commercial forests, recreational forests and strictly conserved/research forests.

The allocation problem can be specified for agents at different levels, representing landowners or users. These can be categorized into three broad groups; entrepreneurs, consumer-producers and social planners. An entrepreneur may be a forest logging or management company or a financial asset company owning forestland. These agents solve the allocation problem by maximizing profits subject to certain constraints. Consumer–producers may be family forest owners – commonly referred to as non-industrial private landowners – or community forestry associations, or forest-dwellers.
Consumer-producers maximize their own utility given a set of constraints. Both the entrepreneurs and the consumer-producers are interested in maximizing their own benefits from allocating the forest resources. Thus they ignore the benefits (as well as costs) that accrue to other members of the society (unless they specifically benefit from altruistic or social motives). These privately ignored effects are the *externalities* related to the use of forests. Externalities may be climate related benefits (growing a tree) or costs (deforestation). Externalities are benefits or costs that are borne by someone else in the society than the particular decision maker with respect to whom the problem is defined. It is also these externalities that are included in the social planner's allocation problem. By this inclusion the social planner represents the interests of the entire society. Society, in turn, can be defined to be at the level of a bloc of countries, a nation, a region within a country or a community.

The constraints with respect to which profits or utility are maximized are related to economic, ecological, social and cultural conditions. In modeling work, the economic conditions typically take the form of budget constraints and the ecological conditions are often formulized as laws of motions related to biological growth, or as relations describing management reactions. Social conditions can take the form of legal restrictions, as in the case of limiting timber harvesting rights or imposing a replanting requirement.

It is natural that the allocation of forest resources belongs to the core of forest economics. Besides this, the discipline is interested in allocation of inputs within the entire society between forest sector and other sectors. Thus, a central question may deal with the problem of optimal division of land between forests and agriculture, capital between forest resources and other sectors, as well as labor allocation. From a societal point of view land allocation may be inefficient implying that *welfare losses* are incurred from the misallocation.

Because forest ecosystems are diverse, and because a multitude of substantially variable goods and services can be derived from forests and through forest management, the allocation problem is not as straightforward as that of dividing a piece of land between different uses. It is possible to dedicate a stand of forest for *multiple-use forestry* so that it produces several *ecosystem services* simultaneously. The term *ecosystem management* is used to refer to a managerial approach where the multitude of forests' goods and services forms the basis of management planning.

It is up to scientific research to determine as to how well a forest can supply e.g. timber and biodiversity at the same time, i.e., what are the rates of substitution between different uses of a single forest unit. The question also leads to the question of efficiency in production; is it beneficial to let tracts of forests to specialize into producing certain products and services, or should the emphasis be on the multiple-use of forests. In various instances small and isolated conserved areas do not ensure the survival of endangered species, in which case it makes environmental sense to concentrate conservation into larger land areas. Along with possible economic benefits from *economies of scale*, this would favor specialization in forestland use between conservation and commercial purposes.

Sometimes multiple-use is enforced through policies when e.g. commercial timber production is limited by restrictions to leave certain valuable biotomes uncut. Thus, a policy may be imposed to integrate environmental considerations into forest management.

The optimal allocation question is naturally time- and space-specific depending on the national, societal, environmental and cultural conditions. These factors define the context for the decision making, and ultimately translate, in modeling work, into profit or utility function structures. Not surprisingly, the concept of utility function is a very central one in addressing the optimal allocation of forest resources. Utility is derived from both economic and financial wealth or consumption but also from forests' intangible values such as recreation, amenity or aesthetic values. Also future generations' wellbeing may enter current decision maker's utility function; this can happen automatically by formulizing future period (discounted) utilities into the current utility, or it can happen through specific inheritance motive.

Next, a renowned and basic question in forest economics is discussed and related to the theme of resource allocation.

2.2. On the Classical Optimal Rotation Question: Faustmann and Beyond

Perhaps the single most known problem in forest economics is that of the optimal time of cutting trees, or the optimal rotation age of an even-aged forest. The classical, and correct, formulation of this problem was written by Martin Faustmann in 1849.

The problem of the optimal rotation age can be regarded as a problem of *divestment*. So-called Faustmann rule states that a tree or a stand should be cut at a time when the marginal costs related to the timber value and the land value equal the marginal benefits of leaving the tree or stand growing. This is just to say that the marginal benefits of cutting equal the marginal costs of cutting. This rule thus maximizes profits from commercial forestry.

A noteworthy thing is that Faustmann, in his formulation, accounted for the opportunity cost of the land that a forest is growing on. He did this by taking into account the future rotations of tree generations and the related delay costs of not freeing the land to let the next and the following generations evolve. A curiosity around the Faustmann case is that his teaching and formula were forgotten for a number of decades. Forestry paradigm claiming that the optimal rotation age is one that maximizes the sustainable yield, a rotation longer than that of Faustmann rotation, gained ground among foresters and policy makers.

From scientific point of view this confusion was trivial, because normally profits from managing forests cannot be maximized by maximizing timber production. However, the confusion did affect policies fairly widely and for a long time. For example, national forest policies have been commonly designed around the objective of maximizing timber supply from forests, instead of maximizing profits or utility. Because this has implied longer than optimal rotations, the consequence has been that too much resources may have been held in the form of timber stock as compared to other forms of assets.

There may be other factors that make the optimal rotation age to become longer from what is suggested by Faustmann, and make the optimum in fact closer to that of maximum sustained yield rotation. For example, accounting for the value of carbon dioxide uptake into forests, a carbon rental system could be envisaged where forest owners are compensated for the carbon content contained in their forests on a periodic basis, based on the price of carbon emission trade permits.

Now, accounting for these would make it optimal for the forest owner to postpone the harvesting of trees, but not necessarily infinitely. This in fact is an example of multiple-use forestry, where both timber and climate services are produced. Another possibility to connect forest ownership with climate services would be one, where forest owners received emission rights instituted by a cap-and-trade system, such as the European Trading System (ETS). These rights could be designated against carbon content in mature forests. The owner would have to turn them back at the time of cutting the trees. During the time of holding these emission rights, they would serve as an asset for the owner, thus creating an incentive to postpone the harvesting of the forest. However, this incentive would be dependent on the price expectations concerning both carbon and timber prices.

One might also ask whether a forest owner should be compensated also for the climate benefits of harvested timber down the route to its further uses. Wooden buildings do produce climate benefits as long as they store carbon in the wooden structures. Also, using wood as an energy source produces climate benefits as long as this replaces fossil non-renewable energy sources.

Thus, wooden structures contribute to creating a carbon sink, and wood based energy helps offsetting the impact of burning fossil fuels. If these climate benefits were compensated for the forest owner, this would again change the optimal rotation. However, one can argue that compensating forest owners for these down-the-road benefits would blur the chain of forest-based climate externalities and an incentive system built around them. Externalities should be accounted where they are created. Therefore, for example, a home-owner selecting wood as a material for his house could be subsidized.

The way a forest owner would benefit from this is through higher timber prices, as the demand for wooden homes and thus for timber would increase. On the other hand, a system such as the ETS accounts for the wood energy climate benefits by treating wood as CO_2 neutral energy source. This is based on the notion that forests are a renewable source of energy.

Besides accounting for the climate benefits of standing timber, there are also other reasons why a forest owner would optimally select a longer rotation age than the one suggested by Faustmann rule. Namely, forest owners very commonly care for non-wood values, or amenity (in situ values) of their forests. This fact does imply longer rotation periods and older forests. These older forests produce public goods.

When private forest owners do value these amenity functions of forests, it is an example of *collective action*, where public goods and services are produced by individuals who benefit from them at least as much as it costs them to produce these services. (Note that at this point, nothing is yet said about whether the amount of privately produced public goods is optimal from the society's point of view.)

Of interest here is to link the above discussion about Faustmann and the question of optimal rotation to the discussion of optimal allocation of forest resources. In his model, Faustmann treated time as a continuous variable. However, this classical one-stand model in forest economics can be extended to cover multiple stands, and presented analogously as a discrete-time model version. And once this is done, the question of optimal cutting time turns to the question of optimal periodic age-class distribution of the forestland. Thus, an optimal timing problem can be translated into an optimal dynamic land-use problem.

3. Forest Economics and Policies

3.1. Sectoral Interlinkages

A large body of forest economic research deals with public policies targeting forest resources either directly, or targeting the forest sector more generally. Policies targeting the forest sector are those that are relevant for the use of forest resources and the way forest sector operates. One should note that the term “forest policies” is typically understood in a more narrow fashion than this. In its narrow sense, forest policies concern institutions and policy tools that focus directly on the use of forest resources, such as forestry laws and regulations, support and information programs for forest management, or organizational structures directly designed for forestry issues. Forest policies can be categorized to fall into the economic regulation, legislative regulation and informational regulation.

The wider angle on the economic analysis of policies concerning forest sector is needed because of the interlinkages between various sectors. Policies planned primarily to affect other sectors may have profound consequences in the forest sector, such as subsidies for agriculture, or the legislation concerning energy sector. The converse is true also – policies meant to affect forest management can have far-reaching repercussions in other sectors; as an example, subsidies for forest residue collection for energy purposes have impacts on the entire energy sector.

Recently interlinkages between forest sector and other sectors such as energy sector, and environmental sector, have intensified. This also highlights the need for a more comprehensive policy analysis. Components of forest resources are more commonly used as a source of renewable energy, and thus the entire forest sector is influenced by policies carried out in the energy sector. For example, the European Union (EU) 10 percent biofuel target for liquid fuels, or the 20 percent twin-targets for CO_2 emission cuts, and for the share of renewable energy out of the total energy consumption, will have profound impacts in the forest sectors both in Europe and globally. Similarly, biodiversity protection policies in many cases target mostly forest environments. Furthermore, there are some overreaching legislature and policy measures specifically in the economic policies that are meant to all sectors including forest sector, such as income taxation policies. In forest economics research these are vitally important policy fields that need to be understood and accounted for.

-

-

Bibliography

Amacher G., Ollikainen M., Koskela E. (2009). *Economics of Forest Resources*, 397 pp. The MIT Press, Cambridge Massachusetts, London England. [This book gives a state of the art treatise on the methods, theoretical considerations and empirical results on the field.]

Arrow K.J., Fisher A.C. (1974). Environmental Preservation, Uncertainty and Irreversibility. *Quarterly Journal of Economics* 88:312-319. [A classic article on environmental conservation.]

Brazee R., Mendelsohn R. (1988). Timber Harvesting with Fluctuating Stumpage Prices. *Forest Science* 34(2). 359-372. [Added the element of variable prices to the optimal rotation analysis.]

Buogiorno J., Gilless J.K. (2003). *Decision Methods for Forest Resource Management.* Elsevier Science, Academic Press. [Wide coverage of numerical problems and solutions in forest management.]

Clark C.W. (1990). *Mathematical Bioeconomics: The Optimal Management of Renewable Resources*, 2nd ed. New York, Wiley-Interscience. [Puts forest economic premises in the wider context of the economics of renewable resources.]

Duerr W.A., Teeguarden D.E., Christiansen N.B., Guttenberg S. (eds.) (1979). *Forest Resource Management. Decision-Making Priciples and Cases*, 612 pp. Philadelphia, W.B. Saunders Company. [A textbook for students of forestry and natural resource management.]

Everyman's right in Finland. *Public access to the countryside: rights and responsibilities*. (2007). The Ministry of the Environment. 24 p. Available at : w w w . environment . fi / everymansright . [An example of how public access to private land can be stipulated.]

Faustmann M. (1849). Calculation of the Value which Forest Land and Immature Stands Possess. Reprinted in *Journal of Forest Economics*, 1995 (1): 7-44. Published originally in German: Berechnung des Wertes welchen Waldboden sowie noch nicht haubare Holzbestände fur die Waldwirtschaft besitzen. *Allgemeine Forst- und Jagd-Zeitung* 25: 441-455. [Corner stone in forest economic literature and foundation for large amount of research.]

Haight R.G., Holmes T.P. (1991). Stochastic Price Models and Optimal Tree Cutting: Results for Loblolly Pine. *Natural Resource Modeling* 5: 423-443. [Example of dynamic programming in forestry use.]

Hartman R. (1976). The Harvesting Decision When a Standing Forest Has Value. *Economic Inquiry* 14:52-55. [Hugely cited classic in forest economics literature.]

Hetemäki L., Nilsson S. (eds.) (2005). *Information technology and the forest sector.* IUFRO World Series Vol. 18. 235 p. [Discusses the impacts of new developments of IT on forest sector.]

Hotelling H. (1931). The economics of exhaustible resources. *The Journal of Political Economy* 39: 137-175 [Tropical rain forests and some boreal old-growth forests are essentially nonrenewable, exhaustible resources.]

Hyde W. (1980). *Timber Supply, Land Allocation, and Economic Efficiency*. London, The Johns Hopkins University Press. [Developed principles of economic analysis on its thematic issues.]

Hyytiäinen K., Tahvonen O. (2001). The Effects of Legal Limits and Recommendations on Timber Production: the Case of Finland. *Forest Science* 47: 443-454. [Shows how legislation can restrict profitability of forestry.]

Khajuria R.P., Kant S., Laaksonen-Craig S. (2009). The Valuation of Timber Harvesting Options Using a Contingent Claims Approach. *Land Economics* 85(4): 655-674. [The theory of real options with contingent claims is used to value the harvesting options of a Canadian forest management case.]

Johansson P.-O., Löfgren K.-G. (1985). *The Economics of Forestry and Natural Resources*, 292 pp. Oxford, Basil Blackwell. [Expanded forest economics to some new directions.]

Koskela E. (1989). Forest Taxation and Timber Supply under Price Uncertainty: Perfect Captial Markets. *Forest Science* 35: 160-172. [Utilizes the 2-period model framework.]

Klemperer W.D. (1996). *Forest Economics and Finance*, 551 pp. New York, McGraw-Hill. [Covers comprehensively the importance of interest rates in financial forestry calculations.]

Kuuluvainen J., Karppinen H., Ovaskainen V. (1996). Landowner Objectives and Non-industrial Private Timber Supply. *Forest Science* 42: 300-309. [Integrates market, forest and landowner objective level data together.]

Lehtonen E., Kuuluvainen J., Pouta E., Rekola M., Li C.-Z. (2003). Non-market benefits of forest conservation in southern Finland. *Environmental Science and Policy* 6: 195-2004. [Valuation estimates of forest conservation.]

Leonard D, van Long N. (2002). *Optimal Control Theory and Static Optimization in Economics*, 353 pp. Cambridge University Press. [A widely used textbook.]

Li N., Toppinen A. (2011). Corporate Responsibility and Sustainable Competitive Advantage in Forest-Based Industry: Complementary or Conflicting Goals? *Forest Policy and Economics* 13(2): 113-123. [Opens up important governance themes in forest-based industry.]

Lintunen J., Kangas H.-L. (2010). The case of co-firing: The market level effects of subsidizing biomass co-combustion. *Energy Economics* 32: 694-701. [Introduces the technology of co-firing of renewable and fossil sources of energy into economic analysis.]

Mitra T., Wan H.Y. (1985). Some theoretical results on the economics of forestry. *Review of Economic Studies* 52:263-282. [Solves a vintage or age-class model of forests.]

Neher P.A. (1990). *Natural Resource Economics, Conservation and Exploitation*, 360 pp. Cambridge, Cambridge University Press. [Develops the concept of intertemporal allocation of resources.]

Nerg A., Uusivuori J., Mikkola J., Neuvonen M., Sievänen T. (2012). Visits to national parks and hiking areas: a panel data analysis of their socio-demographic, economic and site quality determinants. *Tourism Economics*. 18(1): 77-93. [Combines different types of data for a panel econometrics analysis.]

Palo M., Uusivuori J. (eds.) (1999). *World Forests, Society and Environment*, 404 pp. Kluwer Academic Publishers, Dordrecht, London, Boston. [This book links forest sector issues to other sectors on a global and regional scale. 70 writers with diverse backgrounds.]

Pearse P.H. (1990). *Introduction to Forestry Economics*, 226 pp. Vancouver, University of British Columbia Press. [Utilizes basic level economics to give a quite comprehensive coverage of forest economics.]

Prestemon J., Holmes T. (2000). Timber Price Dynamics Following a Natural Catastrophe. *American Journal of Agricultural Economics* 82: 145-160.

Samuelson P. (1976). Economics of Forestry in an Evolving Society. *Economic Inquiry* 14: 466-492. [Gives a nice and somewhat alternative angle to the familiar Faustmann rule.]

Sinn H.W. (2008). Public policies against global warming. *International Tax and Public Finance* 15(4): 360-394. [Introduces the so-called green paradox.]

Sohngen B., Mendelsohn R. (2003). An Optimal Control Model of Forest Carbon Sequestration. *American Journal of Agricultural Economics* 85(2): 448-457. [Integrates cabon rents into the analysis.]

Stainback A., Alavalapati J. (2004). Modeling Catastrophic Risk in Economic Analysis of Forest Carbon Sequestration. *Natural Resource Modeling* 17: 299-317. [Develops a modified Hartman model and applies it to a slash pine plantation.]

Tahvonen O. (2009). Optimal Choice Between Even- and Uneven-aged Forestry. *Natural Resource Modeling* 22(2): 289-321. [Endogenizes the choice between two forest management regimes.]

Tyrväinen L., Miettinen A. (2000). Property prices and urban forest amenities. *Journal of Environmental Economics and Management.* 39(2): 205-223. [Applies the hedonic pricing method.]

Wear D.N., R.J. Huggett, and R. Li. (2011). *Forecasts of forest conditions in the U.S. South under future scenarios for the 2010 RPA Assessment*. USDA Forest Service, General Technical Report. Accessible at w w w . srs . fs . usda . gov / futures / reports / draft / Frame . htm. [A large futures study of forest sector.]

Wollenberg E., Merino L., Agrawal A., Ostrom E. (2007). Fourteen years of monitoring community-managed forests: learning from IFRI's experience. *International Forestry Review* 9(2): 670-684. [A land-tenure and property-rights analysis.]

Zhang Y., Liao X., Butler B.J., Schelhas, J. (2010). The Changing Small-Scale Family Forestry in the United States 1993-2003. In Gan J, et al. (eds.): *Global Change and Forestry: Economic and Policy Impacts and Responses*. New York: Nova Science Publishers. [A review of the roles of family forestry in the U.S.]

Biographical Sketch

Jussi Uusivuori received his Ph.D. in Forest Economics at the University of Wisconsin-Madison in 1990. His MSc. is in Economics from the University of Helsinki. Since 2004, he is Professor of Forest Economics and Policy at the Finnish Forest Research Institute Metla. In his research work, Dr. Uusivuori has applied economic thinking and frameworks in policy analysis. His work covers international trade and market analysis, landowner behavior, forest conservation, deforestation, and climate and energy policies. Jussi Uusivuori has participated actively in governmental policy support and in academic teaching. He has been an invited lecturer in the U.S.A, China and Russia.