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Special problems of forests as ecologic–economic systems ☆

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ABSTRACT

Ecologic–economic systems tend to exhibit greater complexity than systems that are purely ecological or economic. The interactions between the two types often generate nonlinear relations that lead to various kinds of complex dynamics that complicate management and decisionmaking regarding them. Of these, forests have characteristics that lead them to have special problems not usually encountered in the management of such systems. A central one is the long time periods involved managing forests compared to most other such systems. This means that the issues regarding determination of discount rates for valuing future outcomes are more important for forestry management than for many other systems. Also, forests generate a wider range of externalities than do most other ecologic–economic systems, with implications for various hierarchical levels of management. This paper considers the array of these problems as they appear for a variety of forestry management issues.

1. Introduction

Forests are among the world's most important ecosystems, prevailing in regions where precipitation exceeds transpiration and where temperatures are sufficiently warm and soil conditions sufficiently fertile. From the origins of humanity to modern high income economies, forests have provided a variety of services to people, including basic energy from fire, timber, food sources from various animals, and for modern societies such externalities as carbon sequestration, flood control, sources of medicines, esthetics, and others. The development of various property right systems and governance systems has altered how humans have interacted with forests over time.

A crucial part of this has also been the emergence of an awareness of the role of time and efforts to plan the management of forests over time. This has involved both how people choose discount rates to value amenities over time as well as how institutions allow for the expression of these discount rates in the forest management systems. Indeed, the importance of time and discount rates for forests led Irving Fisher (1907) to use forests as a leading example in his innovative work on the role of interest rates in capital theory. Rosser (2005) has shown how complicated patterns of returns over time of various forest amenities can lead to capital theoretic paradoxes and complications within optimal management regimes.

This paper will extend these themes in various ways. We shall reconsider the optimal forestry management scheme in which the discount rate plays a central role. After reviewing some of the results previously presented, a new argument will be advanced that fits with some empirical findings (Amacher et al., 2009) and certain cases. Forests are renewable resources with distinct carrying capacities and are thus amenable to being analyzed using models that have been used for other renewable resources, particularly fisheries. As has long been understood, these are subject to backward-bending supply curves under certain conditions. We shall consider how this can arise for forest products as well, drawing on a few earlier observations of this (Binkley, 1993). As shown by Hommes and Rosser (2001), complex dynamics can arise for fisheries in this case, which can be seen possibly to carry over to forests also. This perspective is partly connected to an approach that emphasizes maintaining something like a near-steady state forest rather than the traditional emphasis on optimal rotation period of a forest, with this perspective arguably more tied to sustainability based on arguments by Kant (2003a).

In the analysis referred to above, a crucial element in the optimal management case is the role of the discount rate. In particular, the backward-bending supply curves only occur for discount rates that are sufficiently high, meaning that as agents value the future less, these dynamic complexities become more likely to occur. This is consistent with arguments regarding chaotic dynamics appearing in dynamic optimization models with high discount rates (Mitra, 1996; Nishimura and Yano, 1996). It may be that these phenomena are more likely to occur in developing countries or areas where poorer populations inhabit forests or are otherwise heavily dependent upon them for basic amenities. It has long been argued that people in subsistence or near-subsistence conditions are more likely to be concerned with their immediate near future, thus effectively exhibiting higher discount rates that may lead to these outcomes.

The final topic of the paper will be to consider various factors influencing the formation of subjective discount rates. These will be

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seen to have arisen from evolutionary forces now hard-wired into modern humans as exhibited by neurological evidence. This discussion will follow arguments in Gowdy et al. (2013) and will also consider normative aspects of this in terms of sustainability concerns that are important in light of the difficult problem of deforestation that confronts many nations in the world today. For higher level planners of forests ethical issues must also be taken into account in the approach to selecting discount rates in these management cases (Khan, 2005; Price, 2005).[1]

2. Optimal periodicity in forest management

The traditional focus of theoretical forestry economics has been to study the optimal rotation time of a forest homogeneous in age and species, with the only value of the forest being due to the timber obtainable at the time it is cut down. The first to arrive at a solution for this problem involving an expected replanting of the same species was Martin Faustmann (1849), although this achievement published in German was long unknown outside of German language circles. The later solution of Fisher (1907) received far more attention, although it was only correct for a forest that is not replanted, with the land being essentially abandoned. Nevertheless, the Fisher solution was intuitively pleasing and simple: cut when the growth rate of the forest's tree volume equals the real rate of interest. As it was, even though Faustmann's solution would not be translated into English until 1968, Alchian (1952) and Gaffney (1957) realized the error Fisher had made, without themselves arriving at Faustmann's solution.

The obvious missing piece for this problem was the matter of unaccounted for non-timber amenities (or Non-Timber Forest Products, NTFPs). Hartman (1976) would resolve this, with the approval of Samuelson (1976a), of the following solution. Let f(t) be the growth function of the wood volume over time, T the optimal rotation period, p the constant real price of timber,[2] r the assumed real interest rate, c the assumed constant marginal cost of harvesting timber, and g(t) the time pattern of non-timber amenities (NTFPs) valued by the decisionmaker. The equation then is

$$\mathrm{Pf'(T) = rpf(T) + r\left[(pf(T)–c)/\left(e^{rT}-1\right)\right]–g(T).} \quad (1)$$

On the right-hand side the first term gives the Fisher solution, the second added to that gives the Faustmann solution, and the whole thing is the Hartman solution, although g(t) is left unspecified. Variations of it can move T to be shorter or longer (even to become infinite, such as if the most valuable thing in a forest is to preserve an endangered species that thrives in its old growth form). As it is, for the case of only considering timber use, the Faustmann solution implies cutting sooner than the Fisher solution so as to get the more rapidly growing younger trees planted sooner.[3]

While the time pattern of g(t), the NTFPs, is important, we must note that it also matters which ones get accounted for in decisionmaking. This will in turn depend on the nature of the ownership and management of a forest as well as its relationship to markets. While poor owners (or users allowed to harvest products from a forest, even if they are not owners) may simply use products for their own use, many owners of a forest, whether individuals, cooperative groups, firms, or state entities, will be selling products on markets. For some owners this will be what matters and all that matters, so that only marketable NTFPs will count in their accounting. As it is, a variety of these products can be marketed, including animal products from grazing, inputs to medicine, and even such things as rights to hunt or fish or sightsee. In addition, some owners will value non-marketed NTPFs, with such entities more likely to be cooperative or state. In such cases the basis of decisionmaking may be some inferred market value or it may be drawn from some other source, perhaps even some internal value, with, for example, conservation organizations focusing particularly on endangered species or carbon sequestration or flood control due to soil erosion. In some forests these goals may conflict, as for example in the US Southeast, whereas carbon sequestration and flood control and carbon sequestration improve with the age of most forests (Plantinga and Wu, 2003), there may be a tradeoff regarding biodiversity if improving carbon sequestration involves a mono-species forest (Caparrós and Jacquemont, 2003).

For the rest of this discussion we shall avoid discussing these last issues. We shall assume that the relevant decisionmaker for a given forest is able to assign some sort of values to the stream of amenities coming from the NTFPs in their forests as given by their forest's particular g(t), and that it does not matter whether those valuations are based on market prices for products to be sold or are simply some internally determined valuation for the particular stream of amenities.[4] As shown in Rosser (2005), varying values over time of these amenities can lead to complications in determining an optimal rotation period for a forest in the context of time discounting as built into Eq. (1).

A simple example of multiple forest products can be seen from the US National Forest in Western Montana as studied by Swallow et al. (1990). Cattle grazing can be done during the earlier years after a clearcut with the grazing benefit maximizing at 12.5 years and then declining. Fig. 1 shows the time path for this grazing function as studied in this case for particular parameter values at that time, with a value of US $16.78/ha being reached at that maximum point, this being a market-determined value.

If one combines this with the price of timber in this forest from that time, then looking at a function of present value (PV) of those amenities over time one finds multiple maximum points over time, one early and one later arising within the appropriate Hartman equation, given r and the growth function of the trees in this forest and their prices and costs of harvesting (assumed constant). In this case, one can estimate marginal opportunity costs for the forest as MOC and marginal benefits of delaying harvest as MBD, and Swallow et al. found all of this to be depicted as below in Fig. 2. In this case, a global maximum occurs at 73 years, although without the grazing benefits it would occur at 76 years from a purely Faustmann equation. As it is, such non-monotonicities in net benefits over time mean that there can be oscillations in the optimal rotation period as r varies as such multiple local solutions can give arise to the reswitching phenomenon (Prince and Rosser, 1985; Rosser, 2005).[5]

[1] That government forestry managers tend to favor lower discount rates due to their longer time horizons than others in governments is seen by the fact that after President Nixon imposes a cross-government 10% discount rate for public benefit–cost analyses, based on estimates of the private opportunity cost of capital (Stockfish, 1969), it was the National Forestry Service that was the first government agency that won a reprieve from this to use a much lower discount rate.

[2] Use of option theory to optimize in the face of stochastic processes was first suggested by Arrow and Fisher (1974) and since followed by many, starting with Reed and Clarke (1990).

[3] The Samuelson approach has been generalized using turnpike theory following Samuelson's (1976b) "periodic turnpike" by Mitra and Wan (1986) and Khan and Piazza (2012). In this approach a multi-aged tree farm will be gradually adjusted to move towards a long-run optimal configuration with a uniform periodicity or rotation time as in the undiscounted case. However, if discount rates are high enough, then optimality may imply chaotic dynamics (Mitra, 1996; Nishimura and Yano, 1996; Khan and Piazza, 2011). Furthermore, this analysis confines itself to the timber use forest case only, although Asheim and Buchholz (2005) consider a somewhat more generalized case.

[4] Methods of determining such non-marketed amenity values for state-owned forests are numerous, and ongoing controversy surrounds them with contingent valuation surveys widely used, but others emphasizing option values, existence values, and so forth used as well. These methods are particularly difficult in forests containing traditional populations such as in the Amazon rain forest (Gram, 2001).

[5] It must be recognized that there are many further sources of potential nonlinearity in multiple use forests. These may include forms of recreation, effects of regulating for climate change, cultural behaviors, and also the discontinuities that can arise when due to poor people possibly possessing lexicographic preferences.