The Design of Forest Taxation: A Synthesis with New Directions

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Amacher, G.S. 1997. The design of forest taxation: A synthesis with new directions. Silva Fennica 31(1): 101–119.

In this paper, different approaches and results concerning forest tax design are reviewed. In particular, comparisons are made between Scandinavian approaches, which rely on the two period model, and North American approaches, which largely rely on the Faustmann model. Existing work is critically evaluated according to several stylized facts that are common among forest taxation problems. These include the second best forest policy environment, joint production of public and private forest goods, the dynamic nature of forest capital, public and private ownership, competition between forest and nonforest sectors, and global policy constraints on taxation design. The gaps in addressing stylized facts are used to motivate new research directions. Problems and appropriate public finance literature are identified for investigating forest tax policy under government budget constraints, fiscal federalism, dynamic forest tax design, open economy forest tax policy, and econometric studies of reform. One conclusion reached from discussing future research is that two period and dynamic models will continue to prove useful in analyzing taxation design from the government's perspective.

Keywords forest taxation, literature review, future research
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Accepted 3 December 1996

1 Introduction

Forest taxation has probably been one of the most frequently studied areas of forestry research in the past 3 decades. Much of the proliferation in literature can be explained by the many different forest policies employed by governments such as taxes and subsidies on the growth of forests, property taxes, and ad valorem taxes, as well as various taxes targeting harvest income, harvest yields, and long term capital gains income or inheritance income.[1] The variety of taxes and government interventions reflect the different problems facing governments and differences in the structures of the forest sector. In virtually all of North and South America, there are also many levels of governments setting policies, from the national centrally located governments to the smallest municipality. All of these governments have varying levels of control over forest taxes, and many implement duplicative tax systems.

The largest variety of taxes is employed in Scandinavia and central Europe. These taxes target forest growth and harvests, and there is little reliance on the basic property tax. This contrasts with the U.S., where forest tax revenue is primarily raised through property taxes based on some rough indicator of market value (Gregory 1986), or taxes are applied to long term capital gains realized when timber is harvested (Boyd 1986). Often market value-based taxation does not coincide with site value (Klemperer 1977, 1982, 1983), so that these taxes do not come close to approximating the site value tax used in Scandinavia. There have been numerous arguments made to implement "modified" property taxes which target the growth potential of forest stands, but these are used in only a few states (Amacher et al. 1991, Williams and Canham 1972, Klemperer 1976). Harvest yield and income taxes also remain less common, with only about 10 state governments currently offering yield tax options for forest landowners (Clements et al. 1986). On the other hand, Sweden employs a nonlinear harvest income tax (Aronsson 1993a), while many Scandinavian countries have forest increment taxes, site value taxes, and taxes applied to harvests (Ovaskainen 1992).

Another important aspect of forest taxation problems concerns forest ownership. In both the U.S. and Canada, large publicly owned forest land exists and provides a large contribution to timber supplies. Public harvesting also is subject to state (or lower government) taxation, and in many cases higher governments make payments to lower governments in lieu of taxation (Boyd and Hyde 1989). On the other hand, nonindustrial ownership is significant in both North and South America and in Scandinavia. Nonindustrial landowners have the dual objective of owning forests for both timber income and nontimber benefits and are affected by taxes differently than industrial owners.

Forest taxation has been subject to much debate in South America and most of the developing country world (especially the Philippines and other parts or south and southeast Asia) (Hyde and Newman 1991, Hyde and Sedjo 1992, Vincent 1990). At present, the most common policies employed by these countries are lump sum subsidies or some rough form of lump sum tax (e.g., see Hyde 1995 for the Bolivian case, Mcgauhey and Gregerson 1982 for other Latin America cases, and Amacher et al. 1996 for the Chilean case). The implementation of forest taxes in these countries is a particularly acute problem, since centrally located national governments have much less control over the enforcement of taxation than their developed country counterparts (Cruz and Munasinghe 1994). However, the vast forests of these countries contribute a great deal to the government's ability to fund activities.[2] One can imagine that similar situations exist in the former Soviet republics.[3]

The purpose of this paper is to discuss emerging issues in forest taxation. We will first draw together existing North American and Scandinavian literature and special forestry problems into a set of "stylized features" of forest taxation. Existing work will be judged by how well these stylized facts are accommodated, and we will then use this to motivate future research. The intent is to show how newer more general public finance literature might be used to enhance our understanding of forest taxation design. We will find though that much of the work in public finance is not yet directly applicable to forestry problems. Thus, suggestions will be made as to how one might modify the existing literature to study the right set of forest taxation problems.

We will concentrate primarily on the choice of forest taxes and their applications. In doing so, we will argue how previous work outlining the effects of forest taxation on landowner behavior and market outcomes should be imbedded into more general problems facing the government. Unlike existing reviews of forest taxation (Boyd 1986, Klemperer 1989) which focus on the effects of specific U.S. capital gains and property taxes, this paper focuses on more general forest tax design problems. It also focuses on recent questions about what system of taxes is optimal. Finally, unlike other review or synthesis articles, this one also serves to compare North American and recent Scandinavian forest taxation literature.[4]

2 Two Approaches for Modelling Forest Taxation

Given the specialty of problems, the specificity of taxation policies, and the differences in government structures and land ownership, it is not surprising that two relatively distinct bodies of literature have developed over the last decade. Although there are certainly some exceptions, these can be grouped into North American and Scandinavian studies. The North American approach has largely been based on timber supply in the Faustmann model of forest management. Research has primarily examined effects on rotation ages and silvicultural investments from imposition of specific property and capital income taxes, including the property tax (Jackson 1980, Chang 1982), yield and harvest taxes (Chang 1982, 1983, Jackson 1980), modified property and productivity taxes (Amacher et al. 1991, Dennis and Sendak 1992), nonlinear harvest income and property taxes (Lippman and McCall 1981, Mendelsohn 1992), and uncertainty (Lippman and McCall 1981, Sun 1994). Nontimber benefits and associated Pigouvian taxes have been introduced into such models as a function of time, despite possible convexity problems (e.g., Englin and Klan 1990, Swallow et al. 1990).

Early tax policy work focuses on biases in forest property tax valuations (Klemperer 1976,82) and the incidence due to this bias (Stier and Chang 1983). When the Faustmann model is used to study forest tax policy, researchers have focused on comparing property or yield taxes based on their excess burdens, with revenue assumed fixed and excess burdens depending only on rotation age but not stand investment changes (Gamponia and Mendelsohn 1987). Stand investment is treated by Rideout and Hof (1986), where errors are computed for excess burden measures that do not incorporate changes in stand investment. Other examples of forest taxation work with stand investment choices include Amacher et al. (1991), Chang (1983), and Jackson (1980). Tax incidence with property, income, and capital gains taxes has been investigated when traditional Faustmann land rents (e.g., Samuelson 1976) and preexisting distortions are present (Kovenock 1986, Kovenock and Rothschild 1983).

With the exception of Lippman and McCall (1981) who model uncertainty in production as a stochastic process, perfect foresight on the part of both landowners and governments has been a common assumption in North American models. Another common assumption is partial equilibrium, with the exception of Boyd and Hyde (1989) and Boyd and Daniels (1985) who study capital gains and income taxation in a static two sector model with endogenous wages and interest rates, and Kovenock (1986) and Kovenock and Rothschild (1983) who allow for equilibrium markets in land allocated between an "Austrian" (i.e., timber) sector and a nontimber sector. With the exception of Kovenock's work, authors have also evaluated taxes independently rather than as a system. Other common assumptions are that the economy consists of a single landowner, all future parameters are constant, and nontimber benefits are a function of time.

Three North American studies are more typical of work from Scandinavia. These are Amacher and Brazee (1996a) and Amacher et al. (1996) who study taxation and incentive design with nontimber benefits, public production, and a revenue constrained government, and Max and Lehman (1988) who study comparative statics of various taxes when landowners value nontimber benefits. With a few exceptions, Scandinavian models of forest taxation are based primarily on two and three period representations of timber supply (Johansson and Löfgren 1985). Uncertainty in second period prices (Koskela 1989a,b), interest rates (Ollikainen 1990), and both interest rates and prices has been addressed (Ollikainen 1993). Landowners are assumed to value nontimber benefits that are a function of the stock of unharvested timber in several studies (Max and Lehman 1988, Ovaskainen 1992, Amacher and Brazee 1996a), and credit constrained landowners are accommodated in Ollikainen (1990), Koskela (1989b), and Kuuluvainen (1990). Finally, econometric studies include estimation of the effects of nonlinear harvest income taxes on timber supply (Aronsson 1990), as well as estimation of the impact of progressive harvest taxes on investment in forest quality (Aronsson 1993b). Brännlund and Kriström (1993) investigate the incidence due to imposing chlorine taxes on Swedish pulp and paper industries, while Aronsson (1993a) investigates the incidence of progressive harvest income taxes on nonindustrial landowners and forest industrial firms.

The North American approach to policy design is based primarily on comparing excess burdens of forest taxes computed for a series of Faustmann rotations or a single rotation. In contrast, Scandinavian work has focused on other policy design problems facing governments, namely the effects of tax structure substitution on harvest supplies.[5] Examples include work that investigates tax switching when revenue collections must be preserved in models of i) price uncertainty (Koskela 1989a) and interest rate uncertainty (Ollikainen 1990), ii) nontimber income taxation (Ollikainen 1991), iii) imperfect capital markets (Koskela 1989b, Ollikainen 1990, 1991, 1993), iv) price and interest rate uncertainty (Ollikainen 1993), and v) markets with preexisting tax distortions or nontimber benefits (Ovaskainen 1992). In the models for i)–iv), landowners are not assumed to choose stand investment or value nontimber benefit production.

Common features of Scandinavian models are partial equilibrium in wages, prices, and interest rates, and evaluations based only on individual taxes. Exceptions are Ovaskainen (1992) who considers taxes as a system of preexisting policies and potential new ones, and Brännlund and Kriström (1994) and Aronsson (1990) who allow for output price equilibrium. Koskela and Ollikainen (1996) study joint optimal yield and property taxation when governments face revenue constraints and landowners value nontimber benefits. These questions among others are studied in one North American piece, Amacher and Brazee (1996a). Stand investment and nontimber benefits have been incorporated into only a few studies (Ovaskainen 1992, Amacher and Brazee 1996a). Finally, Scandinavian models have also focused more on credit constraints and uncertainty, which are virtually absent from North American models.

3 A Comparison of Approaches

The two period approach relies on a single generation of landowner and can be thought of as a short run representation. The Faustmann approach can be thought of as a long run steady state representation. The two are similar when policies are assumed constant in the two period model. This is because the first order conditions in the two period model can be derived in the context of a more general dynamic programming model. In the dynamic programming analogue of the model, if parameters are assumed constant forever, then the two period equilibrium would repeat every two periods, giving long run results that are similar to those obtained in the Faustmann model. This is because the two period objective function can be written as a Bellman equation if second period utility is written as a maximal utility function. Conversely, the Faustmann model can be interpreted as a short run model when one rotation is considered and land rents are exogenous.

The relatively easy incorporation of stand investment changes into excess burden measures is one advantage of two period models. Another is the ability to examine policy design over a cross section of many landowners with possibly different incomes or valuations of nontimber benefits. Such an approach would be important if the government were interested in choosing taxes to achieve redistributive goals.[6] Nontimber benefits also do not appear to suffer the consequences of nonconvexity argued for those that depend on time (Swallow et al. 1990), since in the two period model they are introduced as a function of unharvested forest stocks. Another advantage of the two period model is that it translates well into more dynamic overlapping generations models or models with forest bequests (it is in fact a steady state representation of these models) (e.g., Löfgren 1991, Hultkranz 1992). It would have the same usefulness in studying taxes that affect inheritance income.[7]

On the other hand, the Faustmann approach is inherently more dynamic and, assuming its constancy assumptions hold, can give policy makers an accurate assessment of tax revenue streams over time for specific taxes or for substitutions between taxes (e.g., Klemperer 1983). The Faustmann approach can also be used to study nontimber benefits and associated externalities that depend in a complex manner on the specific age of a stand. Finally, the Faustmann approach accommodates land markets in a simple manner through the opportunity cost of bare land.

The two period model has been used more often in cases where the focus is a forest economy with many nonindustrial landowners. Here, the two period model is useful for studying the role of the landowners' budget possibilities on forest management decisions. Thus, policy issues such as credit constraints, budget uncertainty, and utility of nontimber benefits can be studied easily. The role of budget or credit constraints is absent from Faustmann models. In addition, utility-based Faustmann representations have been proposed (e.g., Johansson and Löfgren 1985). However, the introduction of nontimber benefits depending only on time remains controversial (e.g., Swallow et al. 1990).

Thus, the Faustmann model appears appropriate for the study of a single industrial forest firm with a fixed land base interested in profit maximization, or for a government that is interested in the stream of forest tax revenues from one representative forest owner over time. However, in cases where land changes affect the tax base, where budget and credit constraints are important to tax policy design, and where the choice of taxes is studied over a cross section of many landowners, the two period model appears to be the more appropriate one.

4 Stylized Features of Forest Taxation

Anyone who reads through this vast and growing literature comes to realize that, despite the different approaches, there are several common "stylized features" of forest taxation that make for similar problems and issues. Although these features make the study of forest taxation both exciting and difficult, they also represent challenges policy makers face when choosing and employing forest taxes. In this section, the stylized facts are outlined to determine how well the forest taxation literature has progressed toward incorporating them into formal models of policy design. This will help motivate ideas for future research.

4.1 Forest Policy Environment

The first two stylized features address the forest policy environment, rather than the physical forest resource itself. These features are i) second best policy constraints and ii) many governments. The first feature is evident since forest policies are almost always implemented under "second best" conditions. That is, there are some constraints on government behavior that prevent implementation of a first best taxation system.[8] Governments intervening in the forest sector face three types of constraints, and policy outcomes are second best whenever any of the three constraints occur. First, governments are revenue constrained, either facing formal targets that must be met through application of taxes or having limited moneys to spend on forest sector activities. Second, governments are usually constrained in terms of the types of policies that can be employed; for example, not all forestry activities are taxed in practice. There are few policies targeting stand investments, and virtually none directly targeting nontimber benefits production from forest land. From earlier discussions, this implies that any tax system is potentially distortional to forest management decisions. The third constraint on government policies arises because governments do not implement or change policies in isolation. Rather there are preexisting distortions that make the reform in existing policies or the choice between new ones difficult. In this case, it is well known that introducing new taxes along with their additional distortions may result in a less efficient tax structure than the one currently in place. In fact neutrality of a specific tax may no longer be desirable.

The second feature of the forest policy environment is the many governments involved in policy design. Often, different levels of governments control different forest taxes. However, these governments have their own budget targets, and they are concerned primarily about their own constituencies.[9] This implies that coordination of forest taxes can not be ensured in practice. Instead, governments compete for revenue collections and may behave strategically. Strategic behavior will likely result in inefficient levels of public goods provided from forests and excess burdens that are higher than when all governments coordinate perfectly.

Second best features of forest policy are only beginning to find their way into the forest taxation literature. However, the problems associated with many governments remain unstudied in forestry. In addition, most previous work does not seek to recommend the best normative tax system for meeting a government's revenue constraint.

The concept of an excess burden for a forest tax is a recent development. Excess burden in its simplest form is defined as the loss in landowner income in excess of government revenue collections.[10] Its magnitude depends on how landowners' harvest and stand investment decisions respond to tax changes (Gamponia and Mendelsohn 1987, Rideout and Hof 1986). Gamponia and Mendelsohn (1987) were the first to correctly introduce the concepts of excess burden and efficiency for forest taxation using a Faustmann model. They find that yield taxes are more efficient than property taxes, since the yield tax excess burden is slightly less than that of the property tax. However their model does not include stand investment, which Rideout and Hof show can lead to overestimation of the "site burden" when stand investment decisions are elastic.

Many early studies of forest taxation have evaluated forest tax efficiency based only on neutrality with respect to landowner decisions (Klemperer 1976, 1982, Stier and Chang 1983, Williams and Canham 1972). Stier and Chang find that an unmodified property tax is biased against capital intensive land uses, and tax-induced land shifting makes it difficult to determine where the incidence of such a tax will fall. Thus they argue that forest property taxes should be neutral with respect to land use decisions. However, taxes are introduced into a forest economy that is assumed to be free of distortions. Kovenock and Rothschild (1983) and Kovenock (1986) examine efficiency of forest taxes when there is land market equilibrium between forest and nonforest sectors. They also allow for preexisting distortions in one or more sectors. Contrary to earlier forest property tax work, they show that if capital income taxes are present in the nonforest sector, than the addition of a lump sum neutral tax in the forest sector may be nonoptimal; rather, the best system of taxes is that which jointly reduces all distortions in both sectors. The efficient tax system for the forest sector in this case becomes an accrual capital income tax (based on the annual growth in value of the forest) or an advalorem property tax. Ovaskainen (1992) examines a similar problem in a three period forest economy where landowners are assumed to value nontimber benefits and choose stand investment effort. Nontimber benefits are similar to land rents in that they induce landowners to shift between timber and nontimber production whenever a policy changes. Surprisingly, Ovaskainen shows that the results of Kovenock and Rothschild still hold under these new assumptions.

Several authors discuss the effects of changes in tax structure that preserve revenue collections. Generally, this "tax switching" has been investigated in two period models, where changes are proposed between yield and lump sum taxes in either the present or future period. A common assumption of these studies is that the economy resides on the upward sloping part of the Laffer curve; that is, a point where the marginal revenues are increasing in taxes. The following policy conclusions are reached: In perfect capital markets and second period price uncertainty, a switch made in the timing of lump sum taxation has no affect on timber supply. But changes in the timing of yield taxes will affect timber supply, albeit in an ambiguous way (Koskela 1989a). When landowners are rationed in credit markets, lump sum tax switches invoke changes in current (first period) timber supply responses since wealth effects are present. In a model with interest rate uncertainty, Ollikainen (1990) finds that tax switches toward yield taxes from lump sum taxes in the same period reduce harvesting in that period, and risk averse landowners that represent net borrowers and those that are net lenders respond equivalently in this respect.[11] These results also hold for credit constrained landowners. Under both interest rate and second period timber price uncertainty, many results concerning yield tax substitution become ambiguous.

However, first period tax switches produce identical results in all models. Tax switching involving the second period yield tax is ambiguous in all models (Ollikainen 1993). Finally, assuming second period price uncertainty and perfect capital markets, an increase in labor income taxes with compensating decreases in lump sum taxes will have no affect on timber supply, but increases in a capital income tax (i.e., decreases in interest deductions) compensated by decreases in lump sum taxes produce a decreasing effect on timber supplies (Ollikainen 1991).[12]

Tax substitutions that occur in the long run may affect timber supply differently if landowners can anticipate the switch. For example, Ovaskainen (1992) shows that announced future switches from lump sum taxation will not change timber supplies in the transition period, but announced switches toward a yield tax may cause large timber supply fluctuations in the transition period even though the yield tax may be neutral in the long run. Although all of this tax substitution work is useful for understanding how timber supply responds to changes in the tax structure, it provides policy makers with less guidance about the normatively best structure of taxes to meet specific revenue constraints. However, this work does reveal important tax incidence considerations due to the shifting of harvest supplies over periods, a point also addressed somewhat in Faustmann-based modelling.

Models that incorporate varying government revenue constraints are only very recent in the forestry literature. In the past, results were obtained at only one point on the Laffer curve, so that revenue constraints, when present, were fixed (e.g., Koskela 1989a). Newer work where taxes are chosen subject to minimum revenue constraints demonstrates scope for a system of distortional and nondistortional policy instruments. Koskela and Ollikainen (1996) and Amacher and Brazee (1996a) find that both lump sum taxes and yield taxes are optimal when externalities exist through nontimber benefits, and when governments must raise a fixed amount of revenue. This result is rather robust, given the differences in the models.[13] Amacher and Brazee also find this when rents to forest land are binding, and either i) nontimber benefits are absent or ii) the government and landowner have equal valuations of nontimber benefits. In all cases, the lump sum tax should be used to raise a certain amount of revenue while the yield tax should be used to correct for externalities due to nontimber benefits lost through harvesting. In addition the yield tax is appealing with binding land rents, since landowners can avoid the tax by reductions in harvests; this retains forest land in the tax base. Finally, when the government's revenue constraint becomes increasingly binding, the yield tax is optimally zero. This is because the government cares relatively less about nontimber benefits and may not seek to correct externalities at all.

Other stylized features of forest taxation are related to characteristics of the forest resource. They are i) joint production of private and public goods, ii) the dynamic nature of the forest resource, iii) public and private ownership of forests, iv) competition of the forest sector for factors of production with other sectors of an economy, and v) the global forest economy.

4.2 Joint Production of Public and Private Goods

The possibility that landowners derive utility from nontimber benefits represents an important dichotomy among forest taxation models, from the standpoint of both the government and the landowner. In the Faustmann model, nontimber benefits are modelled as a function of time. Englin and Klan (1990) derive Pigouvian taxes in such a model when the government and landowner have asymmetric valuations of nontimber benefits. They find that the optimal type of Pigouvian tax depends on whether nontimber benefits are derived from young or old trees, and whether forests grow fast or slowly. When nontimber benefits accrue to older trees, the best policies are those that lengthen the rotation. These include yield and severance taxes, and the unmodified property tax based on accrual of forest value if trees are fast-growing.

However, Englin and Klan's analysis does not serve to recommend the normatively best system of taxes when externalities are present. Work in two period models has been slightly more revealing in this respect (Max and Lehman 1988, Ovaskainen 1992). Studies employing the Faustmann model introduce nontimber benefits into the profit function, while those employing the two period model include nontimber benefits as a utility measure for the landowner. Thus, nontimber benefits represent rents to the stock of unharvested timber, much like land rents in the Faustmann model. The presence of rents to the stock implies that harvesting and management decisions depend on property and lump sum taxation like the site value tax. Changes in these taxes induce landowners to substitute between timber and nontimber production, thus affecting harvest supplies. All types of forest taxes become distortional. Max and Lehman confirm this, showing that the effects of various taxes are ambiguous, although they do not decompose forest decisions into wealth and substitution effects. Ovaskainen (1992) formally derives a landowner's wealth and substitution effects due to shifts between nontimber and timber production, and he also argues the importance of defining excess burdens to accommodate resulting changes in all management activities with tax changes.

Policy design in economies with nontimber benefits becomes difficult, because the government usually can not tax nontimber production. The absence of taxes on nontimber production implies that any tax system is necessarily second best. That is, since all goods are not potentially taxable, a proportional system of taxes and subsidies (i.e., a first best system of policies) can not be employed to raise revenue without distortions (Atkinson and Stiglitz 1980).[14] Some progress has been made in understanding how changes in the tax structure affect timber supply from landowners who value nontimber benefits (Ovaskainen 1992). Changes in lump sum taxes induce Income effects (since these taxes do not separate from first order conditions).[15] However, when the landowner and government have symmetric valuations of nontimber benefits, lump sum taxes remain efficient. When landowners undervalue nontimber benefits relative to the government, the property tax rate should be reduced.

4.3 The Dynamic Nature of Forest Capital

The dynamic nature of forest capital distinguishes forestry markets from many other capital markets. Not only does forest production contribute to governments' uncertainty about the future forest tax bases and landowners' uncertainty about future prices, but among scholars of forest taxation many debates in the last 30 years have focused on finding the best tax that does not penalize owners for the long term nature of forest production (e.g., Klemperer 1976, 1982, 1983, and Williams and Canham 1972 are early examples). The consensus from this body of literature is that yield and harvest income taxes, payable at harvests rather than early in a rotation, or some type of "fair" property tax that accounts for differences in forest quality and production capability, are the most efficient taxes.

Dynamic forest production also means that forest owner responses to policies may be unlike capital owners in nonforest sectors. Forest landowners may have time to react to announced or expected changes in taxation, but this response will not always be immediate. This response is probably also not equivalent to the case where the landowner is surprised by a change in specific taxes, as all models of forest taxation currently assume. This is because short run changes in harvesting and stand investment may be very different than the long run response. It is also possible that the intertemporal transition between policies is as important to taxation design as the choice of taxes.[16]

Finally, all existing forestry models currently assume that governments commit to using a specific policy system. The optimal adjustment of the tax system over time also remains unstudied.[17] Researchers have also not yet studied how anticipations of landowners to changes in taxes affect forest markets and government revenue collections.

One area that has been addressed considerably is the effect of forest taxation under uncertainty. A Faustmann version of this work includes Sun (1994) who studies the effects of lump sum and distortional cost sharing incentives on stand investment. His model and results are quite similar to two period models that study harvest taxes and lump sum taxes. He measures the effects of future price uncertainty on harvests and stand investment, assuming Samuelson-type exogenous land rents are present. A risk compensation subsidy is considered which includes either distortional (i.e., cost sharing) or lump sum payments. The results are inconclusive, since the relative strengths of the substitution and income effects are ambiguous, as Koskela (1989a,b) found in the two period model. Another example of uncertainty in the Faustmann model is Lippman and McCall (1981). They show, in a model without stand investment, that progressive income taxes generally decrease harvest supplies. However, a proportional tax based on increases in forest yields over time can be neutral with respect to harvest decisions. When uncertainty is introduced, the inefficiency of progressive taxes is reduced.

Uncertainty work in two period models concludes that all forest taxes may be nonneutral due to wealth effects that depend on the landowner's preferences for risk aversion. Moreover, a landowner's harvest decisions depend on their consumption decisions (i.e., the models are not separable). Decreases in income induced by lump sum increases in taxes can result in the landowner maximizing utility at a different point of their utility function surface. Less willing to accept risk, the landowner may harvest more and increase current timber supplies. Yield taxes remain ambiguous in their effects due to substitution effects (Koskela 1989a). When credit constraints are imposed on forest landowners, there are additional liquidity effects. However, these liquidity effects are not important to qualitative conclusions. Uncertain interest rates encourage increased harvesting by borrowers (Ollikainen 1990). The behavior of risk averse net lenders of capital is the reverse, and thus there is a dichotomy of the effects of forest taxes and interest rate uncertainty with the basic price uncertainty case. These differences are magnified if some of the landowners are credit rationed. Assuming both future interest rates and prices are uncertain, Ollikainen (1993) uses a mean-variance approach to show, even under constant absolute risk aversion, that wealth affects of lump sum taxes are nonzero.

4.4 Public and Private Ownership

The diversity of forest ownership creates problems for taxation design. The literature has established that landowners differ in their ability to obtain credit. Here the theory of rationing predicts that landowners will face their own subjective interest rate that is a function of their preferences (Kuuluvainen 1990).

Income differences also occur over landowners due to differences in forest quality and landowner characteristics. Forest quality differences can potentially mean that increasing taxes should be applied to land of increasing quality, as argued by Klemperer (1983) and Williams and Canham (1972). However, Amacher and Brazee (1996b) study a model where land varies in quality and the government in budget constrained. They find that regressive rather than progressive taxes are efficient if landowners of the highest quality land also have the relatively lower incomes. In this case the government may seek to subsidize high quality forest land to increase revenue collections. In practice, nonlinear taxes are increasing in forest quality, since increasing forest quality is revealed through increases in the harvests of landowners.[18]

The multiplicity of landowners offers the government an opportunity to redistribute wealth among the forest sector through its choice of forest taxes. Although the design of taxation under redistribution has not been studied in forest taxation,[19] it has been argued as an objective of public forest management in the U.S. (Daniels et al. 1991). The implications for many different landowners facing similar taxation systems has also not been investigated, yet could be important in the choice of tax policies.

4.5 Competition for Factors Between Forest and Nonforest Sectors

Forestry production competes with agriculture and other industries for inputs, namely land, labor and investment resources. As the government changes the tax structure, one can expect in small economies that labor markets adjust and marginal land shifts between forestry and the next best use. This is because labor is a nontraded factor of production. However, in large open economies, there are greater effects. Changes in forest taxes will spillover into labor and capital markets, causing adjustment in equilibrium factor demands and prices. In both small and large economies these effects are important in defining the welfare cost of taxation.[20]

There have been relatively few forest taxation studies which include non-forest sectors. Non-forest sectors have been studied by i) including land rental income constraints in either Faustmann or two period models (e.g., Kovenock 1986, Kovenock and Rothschild 1983), and ii) allowing factor or output prices to be determined in equilibrium (Aronsson 1990, Boyd and Hyde 1989, Boyd and Daniels 1985, Brännlund and Kriström 1993).

The first two papers have previously been addressed (see the Forest Policy Environment section). Brännlund and Kriström (1993) allow for output market equilibrium, while Boyd and Daniels' (1985) work is based on a static computable general equilibrium model that allows for both factor and output price equilibrium. Brännlund and Kriström examine the welfare effects of introducing a chlorine tax in the Swedish pulp industry. They derive the incidence of chlorine taxes under the assumption of output price equilibrium, but their econometric example shows that the incidence of the chlorine tax is well approximated by partial equilibrium measures since the effect of the tax on prices is small. This is perhaps due to price taking behavior in world markets. Consider Boyd and Daniels (1985) and Boyd and Hyde (1989), who find price effects from changes in the U.S. forest capital gains income tax to be significant.

Thus far, the main weakness of computable general equilibrium approaches is the static nature of the models. This reduces the policy relevance of these studies to forestry problems. A more complete analysis would require solving the model at each point in time. Moreover, the multiplier information needed to solve these models at the necessary levels of aggregation remains scarce for the forest sector in most countries.

4.6 Global Economy Constraints

There are several political constraints imposed on any government's choice and application of domestic forest taxes. Pigouvian policies may become more important for countries who must implement them to adhere to provisions in the GATT agreement (Trade and environment... 1994). Assuming countries are willing to control their own forest production before imposing tariffs on another country's products, the incidence of the imposed tariff to the rest of the economy is multidimensional. The welfare effects of changes in forest import tariffs will also depend on the welfare costs of imposing taxes on domestic forest production. Thus the reform in any tariff system is related to reform in domestic tax structures. Forest taxation work does not yet provide enough answers about how this reform should proceed, let alone the best set of policies to impose.

5 Frontiers of Forest Taxation

Our discussion of the stylized features of forest taxation reveals many issues that remain unaddressed. Future work should:

5.1 Continue to Develop an Understanding of Tax Policies Under Financial Constraints

Although the most recent forestry work incorporates government revenue constraints into policy design, much additional work is needed. At present, existing forestry studies seek to find the best system of taxes to meet a given fixed revenue constraint. General equilibrium is included by assuming either elastic labor supply or output market equilibrium. However, potentially interesting questions can be obtained from the dual of this approach. In the dual, the government faces a materials balance constraint,[21] where output is equal to demand for goods, or in the forestry case, the demand for factors equals the total supplies (Atkinson and Stiglitz 1980). Equilibrium is included by restricting factors to be employed so that their prices are equal to their marginal products.[22] The revenue constraint is then removed using Walras law and the government chooses quantities, allowing revenue to vary. With this dual approach, the following question can be addressed: *How much revenue, relative to other sectors, should the forestry sector* *provide the government?* A related issue concerns the optimal size of the forest tax base. In the early forest property tax literature, authors questioned whether marginal (lower quality) forestland should be subject to the same taxation as higher quality land, especially if taxation of marginal land shifts its use out of forest production. Recently, research in problems where governments seek to raise the most revenue from taxation of commodities suggests that goods should be included in the tax base if they have relatively high substitution elasticities with each other (Wilson 1987). It becomes an empirical question whether nonmarginal and marginal forest land are substitutable. One important difference between forest land and commodities studied in public finance is the presence of nontimber benefits. Future work should examine the following question: *How should the substitution of timber and nontimber benefits on forest land and differences in forest quality be used to determine its taxability?*

A government's financial position is important to the environment as well. If a government's valuation of nontimber benefits is dominated by the bindingness of its revenue constraint, the chosen tax structure may not result in the optimal level of public goods for the global economy. Witness developing countries, where subsidies and liberal concessions are resulting in large scale deforestation needed for growth of the economies (Hyde and Newman 1991). This represents a potential "fiscal externality." Future work should address the following question: *How is the strength of fiscal and Pigouvian externalities important to forest policy design? In particular, are nontimber benefits over or under provided in an economy where fiscal externalities dominate?*

Another potential application of optimal taxation theory is a more complete study of forest capital income taxes. The forestry literature maintains that the presence of a capital income tax is important for tax substitution results. However, the question should also be asked: *If the government needs to raise revenue from forest taxation, should the forest capital tax be imposed if other taxes are available?*[23] A related question continues to be: *What is the best normative system of forest taxes under all of the situations discussed in the literature, including credit constraints, various uncertainties, and political constraints?*

5.2 Identify the Inefficiencies of Fiscal Federalism in Forest Policy Design

The problem of tax choice under many governments is a recent issue in public finance. When governments fail to coordinate their policies, either because they face different revenue constraints or care about different constituents, this is known as the fiscal federalism problem (e.g., Oates 1994 provides a recent survey). Existing fiscal federalism models focus on governments at the same level of power who are trying to tax and raise funds to provide public goods to their own residents (Futagami 1989, Wildasin 1988, Gordon 1983), and noncooperative behavior is modelled using Nash equilibria. These models find that governments under provide public goods to nonresidents.

Fiscal federalism is an extremely important potential problem in forest taxation. It is already a problem in the U.S. or Canada, where lower governments rely on tax revenue from higher government public forest harvests. However, fiscal federalism might become more important in Europe, as governments pledge greater cooperation in policy design.

So far, forestry models abstract from several governments, or they assume that all governments coordinate perfectly. However, what is more believable is that governments play strategic policy games, choosing their own policies accounting for the reactions of other governments. Strategic behavior between governments will lead to inefficient levels of forest taxes, and thus inefficient levels of harvesting and nontimber benefit production. Research should be directed at the following set of questions: *What are the consequences of fiscal federalism to forest policy under a variety of strategic behavior assumptions (simultaneous move games, leader-follower games)? How important are fiscal and Pigouvian externalities to miss-coordinated policy design?*

The existing economics literature is not directly applicable to the forestry problem. This is because these models focus on governments at the same level who are competing for capital and labor. They also do not incorporate aspects of dynamic forest capital accumulation, and governments are not assumed to own revenue-generating capital. More research is needed to determine: *What are the consequences in the short run and long run of fiscal federalism when the economy contains appreciating forest capital, and when the government can own part of the capital stock? What measures are necessary to correct such inefficiencies?* Since forest production is dynamic, strategic behavior by a government will not be limited by the choices of forest taxes in just one time period.

5.3 Investigate Dynamic Forest Taxation Design

Forest taxes are similar to productive capital taxation in the public finance literature (e.g., Judd 1991, 1985, 1987). However, these studies are not directly applicable as they are based on the assumptions that i) capital depreciates, and ii) capital does not produce public goods. The types of agents in the economy also abstract from forest landowners. Thus there is much scope for studying forest taxation in a capital-theoretic model. Perhaps the easiest way to move from the large collection of two period literature to more dynamic issues is to cast social welfare as an overlapping generations utility function. Such a model would assume that each acre of land was owned by a two period lived forest landowner, who bequeathed or sold the land to the next two period lived forest owner at the end of his/her life. At any point in time, the forest economy would consist of overlapping generations of landowners.

Several policy questions could be studied in this more dynamic generalization, for example: *How do the effects of forest taxation to timber supplies differ in the short run and long run?* More importantly, *How do government preferences for nontimber benefits and revenue generation affect the optimal set of taxes in both the short run and long run?*, and *What are the implications for transitions in tax structures over time?* Since the two period model approximates a steady state in the overlapping generations model, the more interesting results may be transitional effects and long run welfare costs of policies.

In many developed economies long run timber supply is critically dependent on timber bequests of nonindustrial landowners to future generations. Thus, important issues to ask in dynamic tax problems include: *How do taxes affect long run bequests and the accumulation of unharvested forest capital in the economy.*

There are many examples in the public finance literature that employ overlapping generations (OLG) models to study consumption advalorem taxes, lump sum taxes, and interest income taxes when productive capital is present in the economy (Ordover and Phelps 1979, Park 1992). There are also several papers that study the OLG model with uncertainty in either government policies (Laitner 1990), in wages (Hamilton 1987), or in production (Sargent 1987). However, these models are not suitable for forestry applications. They assume that consumers are holders of capital, and uncertainty is usually introduced into consumer wage income. They also assume that growth in the economy occurs through labor growth and that capital depreciates. In the forest sector, income uncertainty due to production is probably more relevant than wage uncertainty, since labor costs are incurred only periodically. Further, growth in the forest sector over time should be described by land and forest capital changes.[24]

The anticipations of forest landowners to policies and the effects on timber supply also remain to be studied. Although two period models can accommodate uncertainty in second period prices (which is perhaps equivalent to uncertainty landowners may have about future yield tax policies), these models can not be used to measure the effects on timber supply of policy announcements in the first period, versus a surprise policy in the second period. To do so would require that the government is assumed not to commit to a forest policy. Commitment is a common assumption in forest tax models.

The reactions of landowners are important to government revenue, externalities, and forest investments. The short-run response of a landowner will depend on whether they are surprised by a policy change, and how elastic are their expenditures on stand investments due to tax changes.

However, the long run response will depend on changes in forest capital accumulation occurring over the entire time path of the economy, and this will be affected by short run responses. Thus, it would be useful to answer the questions: *How does timber supply respond when landowners anticipate changes in the tax structure? Is this different than the response when landowners are surprised by government policy?* The government's application of policies to raise revenue and to control for externalities could be quite different under these situations. Essentially the government has an additional policy instrument at its disposal; therefore, the question remains: *Can the government gain by exploiting landowner anticipations to correct externalities and raise revenue in the short and long run?*

Anticipations of policies in models of capital growth have been examined for interest income taxes and simple commodity taxes (Judd 1985). Laitner (1990) extends Judd's analysis to an overlapping generations model. Both of these studies suffer in their applicability to forestry problems for the previously mentioned reasons.

Another area missing from the forest taxation literature is the issue of optimal timing of taxes and the consequences of governments that do not commit to future policies. The general public finance literature has shown that the rankings of optimal tax systems are not preserved when the government prefers to wait until the second period to determine tax rates for that period. Rogers (1987) is the most relevant of these studies to forestry problems. She assumes that consumers supply labor to obtain income, so the model is similar to the forestry problem if we view harvests as an addition to income, treat forest labor in the usual manner, and impose equilibrium in factor markets. Finally, existing studies of forest tax switches in two period models abstract from administrative costs. It is well known that administrative costs are incurred whenever new taxes are imposed (Slemrod 1990 reviews literature surrounding administrative costs). In addition the government incurs adjustment costs whenever changes in an existing tax system are made (e.g., Zodrow 1985). From an efficiency standpoint, excess burdens are biased if marginal administrative costs are not included. Thus, it is important to ask the question: *How important are administrative costs to the choice and application of forest tax systems?* Existing models of tax switching abstract from administrative costs. Therefore one should also ask the question: *How robust are current tax switching results when administrative costs for lump sum taxes and harvest taxes are not equal?*

5.4 Investigate Open Economy Forest Tax Policy

Political constraints due to trade agreements have not been introduced into models of forest taxation. The design of forest taxes will be increasingly related to international policies. Thus, it appears useful to study the following questions: *What are the welfare costs of restrictions in forest tax structures due to international agreements? How should forest taxes be designed subject to these political constraints?*

Further, in many global economies the forest sector may be one of many revenue and employment generating sectors. Many goods are traded and some are not. Goods that are traded in a small economy face world prices, so changes in taxes affect only a readjustment in exchange rates and profits of exporting firms (Gordon and Levinsohn 1990). Conversely, tax changes imposed on nontraded goods, for example labor, cause readjustment in domestic equilibrium factor prices. Hence the efficient design of forest taxation should depend on what products are traded: *What are the most efficient forest taxes in an economy with traded and nontraded forest products and factors? How does the welfare cost of taxation depend on the tradeability of forest goods?* For a discussion of optimal taxation in economies with traded and nontraded goods, or economies with political trade constraints, see Razin and Slemrod (1990). Unfortunately, these models are not directly applicable to forestry problems. This is because only consumption policies are studied, and firms are assumed only to exist to the extent that they set marginal products of factors equal to the factor prices. In addition, firms' profits are also assumed 100% taxable. In forest markets, profits can not be taxed away entirely, because unobserved rents to land or rents to the forest stock from nontimber benefits production can become binding as landowner income decreases.

5.5 Investigate Multiple Ownership of Forest Capital and Distributive Issues of Taxation

Different types of forest owners have not been simultaneously treated in models of forest taxation. In practice, taxes redistribute wealth among nonindustrial landowners, industrial landowners, and forest laborers. The effects of redistribution depend on equilibrium adjustments in labor and capital markets. Since most government's have redistributive goals in mind when taxes are chosen, one should consider the following question: *How do systems of forest taxes redistribute wealth among landowners?* Also, *if redistribution is possible, can it be used to increase social welfare from a given forest tax system?* In the second best case, redistribution of wealth is a significant policy option, since it is possible to achieve a higher level of social welfare from changes in existing tax structures.

5.6 Design Econometric Studies to Test Assumptions of Forest Policy Design and Reform

At present, there is little known about the reasonableness of assumptions imposed in forest taxation research. For example, partial equilibrium is a common feature of models. Also, many studies focus only on taxation of harvests but not on taxation of interest income. In practice, the quantitative effects of these two policies on landowner behavior and government revenue collections may not be equal. Yet there is little empirical knowledge about the quantitative effects of forest taxes. One difficulty with empirical studies is that forest tax systems have been changed relatively infrequently in practice. As a result, it is difficult to estimate relationships between marginal tax revenues and different forest policies.

The lack of empirical forest sector data over time also makes it difficult to estimate welfare costs associated with forest taxes. The welfare cost is defined as the change in income of the forest landowner divided by the changes in government revenue (Auerbach 1985). It depends on landowner income and harvest elasticities with respect to each tax. Once welfare costs are computed for a variety of taxes, reform of the tax system will improve social welfare if small adjustments are made toward taxes with lower welfare costs. Although welfare costs have been estimated for several agricultural taxes (e.g., see the empirical studies in Newberry and Stern (1987)), they have yet to be determined for forest taxes. The task is not an easy one since changes in government revenue from changes in forest harvesting can take many years to be realized.

One potential future use of computable general equilibrium models could be to gain an understanding of the quantitative effects of forest taxes to landowner behavior and government revenue through simulations. Simulations can be constructed for a range of forest production and ownership assumptions. The simulations can also be used to test the sensitivity of equilibrium factor and output market prices to changes in forest taxes. Further simulations are also needed to incorporate nontimber benefits into landowner objectives, to study the effects of shifting tax bases on equilibrium forest markets, and to incorporate various levels of forest production (both raw material and finished goods) into the second best policy problem. At present the highly aggregative nature of computable general equilibrium models make them less applicable to a range of landowner types.

Finally, most alternatives to property taxation throughout the U.S are optional. Relatively little in known about why landowners do not adopt certain tax options, particularly when the theory supports that they should. Dennis and Sendak (1992) is a recent example of an empirical study aimed at determining participation in Vermont's use tax program. They find that landowner characteristics and infrastructure are important explanatory variables. Before tax systems can be designed with confidence, the understanding of how landowners respond to new taxes and changes in existing taxes needs continual refinement.

6 Concluding Remarks

The new forest taxation problems are exciting and will probably lead to as voluminous a literature as already exists. Proposing these new directions would be incomplete without a statement of the appropriate future models. As forest taxation work progresses from the landowner problem to the one facing a government that must choose between policies, the two period and related dynamic models will likely emerge as the more useful ones. They suffer less from the problems of multiple landowners and multiple acres inherent in the Faustmann approach. The specification of nontimber benefits, which should always remain a critical piece of good future forest tax work, also suffers less from convexity problems in the two period model. The Faustmann approach has less relevance empirically, since tax-induced shifts of only a few years are common results, and these shifts are probably of little consequence to landowners who are motivated by short run demands (such as mill constraints) or cash requirements (for nonindustrial landowners). However, the two period approach should translate quite nicely to cross sectional studies of tax induced changes in the forest land base.

Acknowledgements

I thank Jari Kuuluvainen, Markku Ollikainen, Ville Ovaskainen, Bill Hyde, and seminar participants at the Forest Research Institute, Helsinki, Finland for comments on earlier drafts of the paper.

Notes to the Text

1. See Klemperer (1989) and Boyd (1986) for a discussion of US tax policies, Ovaskainen (1992) for a discussion of Finnish tax policies, Aronsson (1993a,b) for a discussion of Swedish taxes, Forestry policies... (1988) for European forest taxes and policies, and Hyde and Newman (1992) for a discussion of taxes in many developing countries.
2. Hyde and Kuuluvainen (1995) report that, in Lao PDR, revenues from forest harvesting fees and taxes support over 2/3 of the forest ministry's 45 million dollar budget.
3. In the future, developed and developing country taxation issues will become very closely related. Already, international trade policies are beginning to affect domestic tax structures. Certain GATT provisions require that countries imposing tariffs on imports from developing countries to "correct" international externalities from timber harvesting, must themselves correct domestic externalities using an equivalent type of tax (Trade and environment... 1994, GATT Article III). Such a policy represents an additional political constraint that will very shortly be imposed on forest taxation.
4. Several important issues are not addressed in this paper. In particular, we will not address forestry subsidies, although we will mention where taxation models would be applicable to subsidies given their natural relationship. Much of this literature has proliferated in the U.S. due to state-implemented forestry incentives programs. We will also only briefly address the specific taxation issues of capital gains income taxation and property taxation found in the U.S., although Boyd (1986) and Klemperer (1989) provide comprehensive reviews of this work leading up to the 1986 revision of U.S. tax codes. Finally, we will focus on more recent developments in forest taxation over the last 10 or 15 years, as much this work has not yet been adequately evaluated or compared.
5. Klemperer (1983) also examines tax switching in a Faustmann-type single rotation model.
6. Similar goals have been investigated for public forest management in the U.S., where changes in public harvesting distributes income to local communities (Daniels et al. 1991, Hyde and Newman 1992). The two period model may be more tractable for studying redistribution, particularly because incorporation of many landowners and market equilibrium in the Faustmann model is very difficult, as Brazee and Mendelsohn (1990) demonstrate.
7. Hultkranz shows the overlapping generations model is useful to study bequests of nonindustrial landowners.
8. Starrett (1988) provides an excellent discussion of the differences between first and second best policies.
9. For example, in the U.S., states and municipalities control property taxes and some harvest taxes, while the federal government also controls taxes on income and harvest income and manages public harvesting. The federal government pays tax revenue (or payments in leu of taxes) to the states for public harvests that occur on National forests in the state. In Canada, provincial governments control harvests, while local governments levy harvest taxes. In much of the developing world, federal governments allocate public harvests through concessions, but local governments may control some taxes and fees.
10. It can also be defined in terms of utilities (e.g., Tresch 1984).
11. This is true despite the finding that net borrowers harvest more and net lenders harvest less under interest rate uncertainty.
12. In many studies, the term "capital income" tax is used. In Scandinavian cases, it refers to a tax on interest income or income from investments. In some cases, interest rate deductions are also allowed for forest landowners at the same rate as the tax. In North American literature, it refers to taxes applied to capital gains "realized" when timber is harvested (i.e., a realized capital income tax), or

gains that accrue throughout the rotation as the value of stumpage appreciates (i.e., an accrual capital income tax).
13. Koskela and Ollikainen's model assumes second period price uncertainty for the landowner, certain budgets for the government, constant taxes, and fixed stand investment. Amacher and Brazee's model assumes perfect foresight, nonconstant taxes, and allows stand investment to be a choice variable for the landowner. Both models allow for nontimber benefit production.
14. In the common forestry situation, stand investment effort is also not taxed, so that even constant harvest taxes affect forest management decisions.
15. Much in the same way that constant harvest taxes do not separate from first order conditions when stand investment is a choice for the forest landowner (Jackson 1980).
16. Because nearly all existing work is based on the Faustmann model or the two period one, we do not yet have enough information about policy design in transition periods. Ovaskainen (1992) contrasts short run and long run policy design using a three period model. The second period represents the long run steady state when all parameters are constant. He shows that harvests are equal to growth. Qualitative forest taxation results in the long run and short run are similar. For example, lump sum and profit taxes are neutral with respect to steady state harvest supply. Like Faustmann models (e.g., Chang 1983), permanent yield tax increases decrease timber supplies, as do advalorem property tax increases.
17. However, work in other areas has shown that permanent emissions tax design (with commitment) and interim tax design (with no commitment) can be very different (Malik 1992).
18. Aronsson (1993) provides an econometric procedure to estimate roundwood supplies under the Swedish example of the harvest income tax, where tax rates are increasing functions of harvest income.
19. Aronsson (1990) considers redistribution of income over forest industry and landowner when harvest income taxes become increasingly progressive. he finds that virtually all of the incidence of progressive harvest income taxes falls directly on the landowners due to elasticities of landowner management responses.
20. Spillover of forest policies to nonforest sectors is also important to environmental policy design (Cruz and Munasinghe 1994). Although forests represent significant tax bases throughout the world, their exploitation for revenue and development creates external costs due to lost biological diversity and other nontimber benefits. Thus, the government should have as an objective determining how much revenue the forest sector should optimally generate, or how much subsidization of the forest sector should occur relative to other sectors.
21. The materials balance constraint can incorporate open economy issues by the introduction of export supplies to the rest of the world, as well as the exchange rate (Razin and Slemrod 1994).
22. Unfortunately, it may abstract away from nontimber benefits production, since landowners' factor price equations become quite complicated.
23. The public finance literature would seem to suggest little support for the forest capital income tax. Judd (1985, 1987) shows that, even when the government has redistributive goals, a tax on depreciating capital is optimally zero in the long run. One wonders whether this result would hold for forest capital when credit constraints already impose distortions in the landowner's perceived cost of capital (e.g., Kuuluvainen 1990).
24. The recent overlapping generations models in forestry provide an important starting point for more dynamic policy design. However, they are currently unsatisfactory since each individual is assumed to own one tree. As the population increases, the number of trees increase. This ignores important land constraints.

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The editors of Silva Fennica and Acta Forestalia Fennica would like to extend their sincere thanks to the following scientists for reviews of manuscripts completed in 1996.

Tuula Aarnio
Bengt Andersson
Erkki Annila
Mike Apps
Mats Bergman
Pete Bettinger
Egbert Beuker
Christer Björkman
Finn H. Braekke
Joseph Buongiorno
Ola Carlén
Wolfgang Cramer
Raymond L. Czaplewski
Steven E. Daniels
Henrik Eckersten
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SILVA FENNICA Vol. 31(1), 1997

The Finnish Society of Forest Science
The Finnish Forest Research Institute

Printed by Tammer-Paino Oy, Tampere, Finland

ISSN 0037-5330

9 770037 533017

Cover: Jarmo Koivunen