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FOREST TAXATION, TIMBER SUPPLY, AND ECONOMIC EFFICIENCY

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ACTA FORESTALIA FENNICA 233

FOREST TAXATION, TIMBER SUPPLY, AND ECONOMIC EFFICIENCY

Metsäverotus, puun tarjonta ja taloudellinen tehokkuus

Ville Ovaskainen

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The effects and relative efficiency of alternative forest taxes are analyzed theoretically. The Fisherian two-period model of consumption, savings and timber harvesting is extended by incorporating the management intensity decision and deriving the concept of long-run timber supply. The effects of lump-sum (site productivity), realized income (yield) and *ad valorem* property taxes on short-run timber supply, management intensity, and long-run timber supply are established. As the core of the study, the alternative taxes are compared in order to determine the appropriate forest tax regime in terms of production efficiency. The efficiency criterion generally requires that the excess burden of taxation at any given tax revenue should be kept to a minimum. The study distinguishes between an initially undistorted economy and an economy with pre-existing distortions due to capital income taxation (interest charge deductions). When the effects on forest management decisions of forest and capital income taxes are considered as a whole, a neutral forest taxation is no longer efficient. The nontimber benefits of a forest are incorporated to examine the robustness of the tax results with respect to the objective function. Finally, forest tax issues specific to Finland are considered, and administrational and equity aspects are discussed.

Tutkimuksessa analysoidaan teoreettisesti eri metsäverojärjestelmien vaikutuksia ja suhteellista tehokkuutta. Fisherin kulutus-säästämismalliin perustuvaa puun lyhyen aikavälin tarjonnan mallia laajennetaan sisällyttämällä malliin metsänhoitoinvestoinnit ja johtamalla pitkän aikavälin tarjontakäsite. Mallin avulla tutkitaan kasvupaikan tuottokykyyn, puunmyyntituloihin ja puuvarannon arvoon perustuvien metsäverojen vaikutuksia hakkuu- ja metsänhoitopäätöksiin sekä puun pitkän aikavälin tarjontaan. Tutkimuksen keskeisessä osassa vertaillaan eri metsäverojärjestelmien taloudellista tehokkuutta. Tämän kriteerin mukaan tulisi yleisesti ottaen minimoida verotuksen tehokkuusrasitus kullakin annetulla verokertymän tasolla. Tarkastelussa erotetaan kaksi eri tapausta. Toisessa lähtötilanteen oletetaan edustavan tehokasta resurssien allokaatiota, toisessa taas taloudessa on ennestään muiden pääomatulojen verotuksesta (korkovähennyksistä) johtuvia vinoutumia. Kun metsän ja muiden pääomatulojen verotusta sekä niiden vaikutuksia metsätalouteen tarkastellaan kokonaisuutena, neutraali metsäverotus ei enää ole tehokas. Tulosten herkkyyttä tavoitefunktion suhteen tutkitaan sisällyttämällä malliin metsän maisema- ja virkistysarvot. Lopuksi tarkastellaan yksityiskohtaisemmin Suomen metsäverotusta sekä arvioidaan lyhyesti metsäverotukseen liittyviä hallinnollisia ja oikeudenmukaisuusnäkökohtia.

Keywords: forest taxation, timber supply, economic efficiency, two-period model, comparative static analysis.
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List of frequently used symbols

Roman letters

C	Carrying capacity of the site (saturation stock)
c_i	Consumption in period i
D	Determinant (of the Hessian matrix); demand curve in illustrations
E	Management intensity (silvicultural effort)
F(K,E)	Forest growth as a function of growing stock and management intensity
H_i	Timber supply (harvest) in period i of the representative forest owner
H	Short-run timber supply (current harvest)
h	Long-run steady state timber supply (sustainable harvest)
I	Exogenous (non-forest) income
K_i	Growing stock of timber, after the harvest in period i ($K_1 = Q - H_1$)
L.H.S.	Left-hand side of an equation
M	Density of maximum sustained yield
MSY	Maximum sustained yield
p_i	Stumpage price in period i
Q	Initial stock of timber (exogenously given)
q	Quantity traded in the timber market
R.H.S.	Right-hand side of an equation
r	Market rate of interest
S	Net savings (S > 0 saving, S < 0 borrowing); supply curve in illustrations
T^0	Tax revenue requirement
U	Utility function, as an additive separable function $U = \sum \beta^{i-1} u(c_i)$ of consumption
$u(c_i)$	Subutility function for consumption in period i
V	Utility function, as an additive separable function $V = \sum \beta^{i-1}\left[u(c_i) + v(K_i)\right]$ of consumption and forest-related amenities
$v(K_i)$	Subutility function for forest-related amenities (standing stock) in period i
w	Unit cost of silvicultural inputs
x_i	Tax exemption for regeneration areas (unit harvest subsidy)

Greek letters

α_i	*Ad valorem* property tax in period i
β	Rate of time preference (subjective discount) factor, $\beta = (1 + \rho)^{-1}$
Γ_i	Modified site productivity tax in period i
γ_i	Gross yield tax in period i
δ	Management subsidy (proportion of management cost)
κ_i	Accrual income tax in period i
Λ_i	Lump-sum tax (unmodified site productivity tax) in period i
π_i	Profit tax in period i
ρ	Subjective rate of time preference
τ	Capital income tax (rate of interest charge deductions)

Preface

The present study on forest taxation, timber supply and economic efficiency was carried out in the Department of Forest Resources of the Finnish Forest Research Institute. I wish to thank the Institute and the Department for adopting the topic as part of its research program, and for providing me with excellent working conditions.

Throughout the work, the support, encouragement and experienced advice of my teacher and supervisor, Professor Päiviö Riihinen, has been most important. Also, I am particularly indebted to Professor Erkki Koskela of the Department of Economics, University of Helsinki, whose guidance and suggestions on various versions of the manuscript much increased my understanding of what I was doing. He also made exceptionally detailed comments on earlier papers, some of which have been incorporated into the present thesis.

This work has greatly benefitted from the deliberated comments of a number of my colleagues. Special thanks are due to Lauri Hetemäki, Jari Kuuluvainen, and Heikki Pajuoja in the Department of Forest Resources. Their uncompromising but constructive criticism on the first version of the manuscript decisively helped to clarify the argument. Robert Mendelsohn, of Yale School of Forestry and Environmental Studies, Markku Ollikainen of the Department of Economics, University of Helsinki, and Jussi Uusivuori, Pellervo Economic Research Institute, all made valuable suggestions at the final stages of the manuscript. Besides those mentioned by the name, thanks are due to a number of anonymous reviewers and participants of various seminars for comments on papers that have directly or indirectly contributed to this work. Naturally, responsibility for any remaining errors or omissions is mine alone.

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Ville Ovaskainen

1 Introduction

1.1 Background

The forest taxes most commonly employed can be classified into three broad categories. First, *site productivity* (site value) *taxes* are annual taxes based on the forest's estimated average yield by site quality, irrespective of the actual harvest or timber stocking. Such taxes are used in Finland, several states in the U.S., France (by stand category), and on small properties in Austria (Boyd 1986, Leikas 1990). In Finland and France, seedling stands are tax exempted. Secondly, *yield taxes* are realized income taxes levied on the value of harvested timber at the time of harvest. Varied forms of yield taxation are applied in Sweden, Norway, Germany and several states in the U.S. (Boyd 1986), as well as on larger properties in Austria. In some countries, harvests in excess of the woodlot's sustainable harvest are exempted (Sweden) or taxed at a reduced tax rate (Germany, Austria), which actually resembles the taxation of accrued income (realized income plus any change in the value of the standing stock). Thirdly, *ad valorem property taxes* are levied annually based on the market value of the forest property, including the value of the standing timber and land or timber alone. The property tax is the traditional form of forest taxation in the U.S., and is a major source of timber revenue for local governments in most of the 50 states (Boyd 1986).

Most of the economic research on forest taxation originates from the U.S. Much of the early literature was based on Fairchild's argument concerning the "deferred yield bias" of the property tax. According to this, any given property tax rate implies a higher tax burden when applied to forestry, with its long production period and periodic cash flow, than for properties with annual cash income. This supported a widely held belief that the property tax is inherently biased against forestry. It has been pointed out, however, that the argument no longer holds if forest value growth is viewed as accrued income reinvested in forestry, rather than deferred income (for references, see e.g. Klemperer 1977, Boyd 1986). This is because, by the Haig-Simons comprehensive definition, a period's income equals realized income (or consumption) plus any capital gain/loss.

Much attention has been paid to the effect of alternative forest taxes on the site value, i.e. discounted value of after-tax revenue. Klemperer (1976, 1977, 1978, 1982) has introduced the term "site burden" to describe the relative tax-induced reduction in land value. These analyses have assumed forest management decisions to be independent of the form and level of taxation and taxes to be fully capitalized into lower site values (tax incidence is considered in Stier & Chang 1983).

An important line of research has established the effects of various forest taxes on the optimal rotation length and management intensity (e.g. Chang 1982, 1983). Thus, the effects of common taxes on management decisions are fairly well understood. However, conclusions concerning the *economic efficiency* of alternative forest tax regimes are limited or even misleading.

First, the concept of "site burden" fails to correctly measure the relative efficiency of the taxes. As tax-induced distortions in management decisions are not taken into account, the measure is just the present value of the tax revenue collected. While a well-known concept in the general tax literature, excess burden – the present value of lost income from tax-induced management distortions – was not established as the appropriate measure of the relative efficiency of forest taxes until introduced by Gamponia & Mendelsohn (1987).

Secondly, with the notable exceptions of Chisholm (1975), Kovenock and Rothschild (1983) and Kovenock (1986), the relative merits of forest taxes have been discussed under the implicit assumption that there are no other taxes that influence the forest owners' management decisions (i.e., no "pre-existing distortions" are present). If the point of departure is assumed to be an initially undistorted, tax-free economy, neutral forest taxes naturally appear socially desirable. Nonetheless, neutrality is an appropriate goal of tax policy only when defined with respect to a complete tax system (Kovenock 1986). When tax distortions already exist, a nonneutral tax in a given sector may prove more efficient than a neutral one. In this case, the overall efficiency effects of forest and other taxes should be considered, rather than forest taxes alone.

Thirdly, the forest tax literature has usually assumed that only the income from timber harvesting matters to the forest owner. However, the nontimber benefits from the standing forest, such as scenic beauty and recreation, may also influence management decisions.

Consequently, there is a need to re-examine the economics of forest taxation to clarify the theoretical results, in particular those concerning the economic efficiency of forest taxes. It also happens that the issues which have been central in the theoretical literature are directly relevant to recent debates on forest tax policy in Finland.

Since 1922, forest taxation in Finland has been based on site productivity. The main argument for site productivity taxation has been its lack of disincentive effects on intensive forest management, while the fact that the actual income-earning capacity of individual woodlots is not taken into account has been criticized. On the other hand, suggestions have been made that forest taxation be designed to encourage the use of forest resources. After several changes introduced in 1991, the forest tax system is no longer a simple "lump-sum" productivity tax. To encourage the regeneration of mature stands, the tax allowance for established seedling stands (applied since 1980) was extended, and tax incentives were introduced for reforestation as well as brush control and precommercial thinnings (Metsäverotoimikunta ... 1988, Laki maatilatalouden ... 1990). While the 1991 reform reallocates the tax burden to some extent, a more radical reallocation towards mature stands, to encourage final cuttings, was suggested in the early 1980's. It was proposed that the "flat" productivity tax base per hectare be replaced by a tax base weighted by the age class structure of the forest property (Riihinen 1982, Puuhuollon ... 1985). As the tax burden would increase with stand age (i.e., with timber volume), the regime would in fact resemble an *ad valorem* property tax levied on the market value of the standing stock.

On the other hand, a switch to the taxation of the realized income from timber actually sold has been discussed several times. While early suggestions (Metsäverotuksen ... 1978) involved a "forest account" to alleviate the effects of progressive taxation, interest has recently focused on proportional forms of yield taxation. A realized income tax with immediate expensing was considered by a forest tax committee (Puukaupan ... 1989). A similar proportional tax, with a uniform tax rate on timber and other capital income, was proposed by a committee on capital income taxation (Pääomatulojen ... 1991, Puun myyntitulojen ... 1992). The previous site productivity tax is to be replaced by the realized income tax in 1993.

It is common to the forest tax debate that it lacks a detailed analysis of the allocative effects of alternative taxes. The effects of the new instruments, introduced in 1991, have not been properly established (similarly, the efficiency of the proposed age dependent tax regime remained explicitly unexamined). Most importantly, the proposals concerning realized income taxation seem to ignore the issue of economic efficiency or, at least, fail to consider the effects of the tax system as a whole. As an important example of pre-existing taxes that matter for forest owners' decisions, it should be noted that the taxation of interest income and tax deductibility of interest charges will distort the effective opportunity cost of capital.

1.2 Problem and purpose of the study

This study will focus on the *relative efficiency* of common forest taxes. These include lump-sum taxes, such as the unmodified site productivity or site value tax; realized income taxes, such as the yield or profit tax; and the *ad valorem* property tax. Additionally, a tax on the accrued income (realized income plus any change in the stock) is shown to be equivalent to property tax where efficiency is concerned.

The efficiency criterion has to do with the effects of taxation on resource allocation. The underlying simple idea is that, to allow a maximum production with given resources, raising tax revenue for public expenditure should distort economic decisions as little as possible. More specifically, the *excess burden* of taxation at any given level of tax revenue should be kept to a minimum. The excess burden (deadweight loss) of a tax is the amount that is lost in excess of what the government collects (Auerbach 1985, p. 67), or the loss of welfare above and beyond the tax revenues collected (Rosen 1985, p. 276).

In the case of forestry, the major allocative issues are the investments of capital in the growing stock and silviculture. An efficient allocation requires that the growing stock is maintained and other inputs are consumed to the point where the marginal returns equal the social opportunity cost of capital (i.e., the pre-tax rate of return on investment in other sectors of the economy). The importance of the efficiency criterion should be intuitively obvious: the forest owners' harvesting, or disinvestment, decisions determine the short-run timber supply, while the growing stock and management intensity determine forest growth over time, or the long-run timber supply. As an example of potential tax distortions, taxation may discourage timber harvesting. In this case, there is an inefficiency associated with the waste of short-run production possibilities. Even if a larger growing stock increases the sustainable harvest over time, a misallocation of the resources is implied, as too much capital is tied to forestry relative to other sectors. On the other hand, some taxes might encourage harvesting beyond efficiency. While production would increase in the short run, the sustainable harvest would be reduced in the long run. As the potential distortions are of importance to the performance of economies heavily dependent on the forestry sector, the efficiency effects should be considered when designing forest tax policies.

The approach of the study is theoretical, i.e., alternative forest tax regimes are compared by using an analytical model. The results of the analysis are of importance in two ways. First, they provide suggestive policy implications as such. Secondly, they provide a necessary basis for any related quantitative – numerical or empirical – analysis.

In this study, a theoretical approach is the natural choice by the very nature of the problem. For the efficiency of a tax, only its substitution (as opposed to income) effects matter, and a theoretical model allows these to be dealt with "in isolation". Numerical simulation, for example, could be used for case studies. The results, however, would be tied to a specific set of data rather than being generally valid. Empirical research, on the other hand, would be rather complicated. The basic reason is that determining the efficiency of a tax is not equivalent to simply determining whether or not it has *observed* effects (Rosen 1985, p. 284). A lack of observed effects, for example, does not imply the lack of efficiency losses, since the substitution effects of a tax represent a loss, even if they no more than offset its income effects (The Structure ... 1978). While possible (e.g. Hausman 1981), reliably decomposing the observed effects would be difficult.

In accordance with the above discussion, the effects of forest taxes are analyzed using a model of harvest timing (short-run timber supply), management intensity and long-run timber supply. While evaluating the relative efficiency of forest taxes, the study distinguishes between an initially undistorted economy and one with pre-existing distortions due to other taxes or sectors. More specifically, the main contents and objectives of the study can be stated as follows.

(1) For a more appropriate theoretical model of timber supply, the "Fisherian" two-period model of consumption, savings and timber supply is extended by allowing for an endogenous management intensity and developing the notion of long-run steady state timber supply. Also, the utility derived from the nontimber benefits of the forest is incorporated and their role analyzed in some detail.

(2) The effects of lump-sum, realized income, and *ad valorem* property taxes on forest management decisions are reconsidered. Unlike in earlier literature, their implications are explicitly considered in terms of timber supply and the analysis covers both short-run harvesting decisions, management intensity, and long-run timber supply.

(3) As the core of the study, the relative efficiencies of lump-sum, realized income, and *ad valorem* property (or accrued income) taxes are examined. First, the efficiency of alternative forest taxes is considered in the absence of initial tax distortions. Secondly, a proportional capital income taxation is introduced, and the efficient forest tax regime is then re-solved in the presence of distortions therefrom. The non-timber benefits are subsequently included to consider the robustness of the tax results with respect to the forest owner's and/or policy-maker's objectives.

(4) To evaluate the appropriateness of the forest taxation applied in Finland, given the deductibility of interest charges and taxation of income from assets other than timber, a site productivity tax with exemptions for regeneration areas is analyzed. The efficiency of realized income taxation, to be introduced in 1993, is also discussed.

The problem and contribution of the present study will be further elaborated in Chapter 2 while reviewing the earlier forest tax literature in more detail. At this juncture, it is useful to relate the present approach to the recent literature on the theory of optimal taxation (for reviews, see e.g. Auerbach 1985, Slemrod 1990). Following the typical problem of optimal taxation would amount to a general equilibrium analysis to determine the optimal structure of both capital income and forestry taxation, which minimizes their excess burden at any given tax revenue. While an interesting topic for further research, this is beyond the scope of the present work.

This study chooses to determine the efficient structure of forest taxation *given* the distortions from capital income taxation. Thus, the solution will represent a partial equilibrium solution with respect to production efficiency in the forestry sector alone. The distortionary effects on forest management decisions are corrected, while those on consumption-savings decisions remain. As regards policy implications, this seems to be the realistic approach, since capital income taxation is bound to be maintained. It should be noted that criteria other than economic efficiency also matter for the choice of a "good" tax base (e.g. The Structure ... 1978, Boadway & Wildasin 1984, Rosen 1985). Issues of horizontal and vertical equity, as well as administrational simplicity and costs, will therefore be briefly discussed.

1.3 Outline of the thesis

The report proceeds as follows. Chapter 2 first discusses the merits and drawbacks of earlier theoretical models of timber supply in order to choose an appropriate modelling approach. Earlier studies on the effects of forest taxation and nontimber values on the harvesting decision are then reviewed in some detail. In Chapter 3, tools are developed for the analysis of taxation and timber supply using a three-period version of the consumption-savings and harvesting model with endogenous management intensity. The properties of the growth function are discussed to facilitate the interpretation of the results, and comparative statics are established for both short and long-run supply.

Chapter 4 contains the positive analysis, i.e., the *ceteris paribus* effects of forest taxes on the harvesting and management intensity decisions and long-run timber supply. In Chapter 5, the results of Chapter 4 are applied to a normative analysis which examines the relative efficiency of alternative forest tax bases. The efficient forest tax regime is first determined assuming an initially undistorted economy and next for one with pre-existing capital tax distortions. In Chapter 6, objectives other than commercial timber production are introduced into the forest owner's and/or policy-maker's objective function. Chapter 7 examines the effects and efficiency of the modified site productivity taxation applied in Finland, as well as the realized income tax which is to replace it. Chapter 8 considers the equity issues and administrational aspects of forest taxation. Tax incidence is also discussed to note the aggregate distributional and price effects. Finally, the results and policy implications of the study are summarized in Chapter 9.

2 A review of earlier studies

In this chapter the earlier literature on timber supply and forest taxation is surveyed in detail. In line with the approach and scope of the present investigation, the review focuses on theoretical literature, while empirical or numerical studies are not systematically covered. The merits and shortcomings of alternative theoretical models of timber supply are initially discussed in section 2.1 in order to choose an appropriate modelling approach and outline the developments required (for an introduction to various types of models, see Binkley 1987). Next, earlier studies on the role of forest taxation, as well as nontimber benefits, are reviewed in section 2.2. Section 2.3 summarizes the survey in order to clarify the problem and orientate the present investigation against the background of earlier literature.

2.1 Theoretical models of timber supply

Most of the theoretical literature on the forest management decisions has used the optimal rotation framework, where the timber volume (yield) of an even-aged forest stand is described as a function of stand age. The objective is to maximize the present value of an infinite chain of successive rotations by choosing the optimal harvest age (e.g. Clark 1976, Samuelson 1976, Johansson & Löfgren 1985) and, in more recent versions, management intensity (Hyde 1980, Chang 1983). This approach has also been most commonly used to analyze the role of forest taxation (Chang 1982, 1983, Kovenock & Rothschild 1983, Kovenock 1986, Gamponia & Mendelsohn 1987), as well as nontimber benefits (Hartman 1976, Strang 1983, Bowes & Krutilla 1985, Hite *et al.* 1988, Englin & Klan 1990). The "linear forest" model (Berck & Bible 1984, Johansson & Löfgren 1988, Johansson *et al.* 1989) is a linear programming formulation of the multiple age class management problem, an outgrowth of numerical harvest scheduling models (e.g. Johnson & Scheurmann 1977, Kent *et al.* 1991). Owing to a similar objective, it basically shares the properties of the optimal rotation model.

More recently, the two-period model has been used in several papers dealing with short-run timber supply (harvest timing) under varied assumptions. The model is basically an outgrowth of the Fisherian model of consumption and savings (Fisher 1930), where the consumer is assumed to maximize the utility of consumption over a planning horizon collapsed to two periods (the present vs. the future). This type of models have been widely applied in several fields of research. In public economics, they have been used to analyze the impacts of taxation on consumption and savings, for example (e.g. Atkinson & Stiglitz 1980, Sandmo 1985). Other fields include the theory of optimal investment (Hirshleifer 1958, 1970), as well as agricultural economics (Iqbal 1986).

To analyze timber harvesting decisions, the two-period model has been augmented by an exogenous initial stock of timber and a size or density dependent growth function. This approach has been used, for example by Lohmander (1983), Koskela (1986, 1989a,b), Ollikainen (1987, 1990, 1991), Ovaskainen (1987a) and Kuuluvainen (1989, 1990), to consider timber supply under capital market imperfections and/or price uncertainty. Forest taxation has been a central issue in the papers by Koskela and Ollikainen, as well as by Aronsson (1988, 1990a,b). Max & Lehman (1988) and Ovaskainen (1989) incorporate the utility derived from the nontimber services of the forest.

It would therefore appear that there are two main modelling approaches to be compared. The first one is the present value maximizing optimal rotation, or Faustmann, model with age dependent growth. The second one is the utility maximizing, Fisherian two-period model with density dependent growth. The optimal control models (e.g. Vehkamäki 1986, Omwami 1988, Kuuluvainen 1989) fall, in a sense, in between the two. While the problem is formulated as dynamic rather than static, and a different solution technique is employed, the continuous time formulation is common with the Faustmann model. On the other hand, optimal control models share a density dependent growth function with the discrete time two-period model.

2.1.1 The optimal rotation model

The basic Faustmann model involves choosing the rotation length which maximizes the land expectation value. According to the optimality condition, the forest is cut when the marginal value increment equals the opportunity cost, i.e., the interest on the standing stock and forest land (e.g. Johansson & Löfgren 1985).[1] In other words, the relative rate of value growth equals the discount rate divided by a correction factor representing the land rent (i.e., the delay of receipts from subsequent stands when the current rotation of trees is grown for one more year).[*)]

The objective of maximizing bare land value and averaging out of price fluctuations suggests that the model is basically a long-range management planning tool. Still, if stationary conditions are assumed, the intuition of the cutting rule also applies to currently existing mature stands so that the comparative statics results can be interpreted as supply responses (e.g. Clark 1976, Hyde 1980). For example, when the stumpage price increases, some stands become economically overmature and timber supply tends to increase during the adjustment period. On the other hand, if the amount f(t*) per hectare is cut every t* years from a single stand, the sustainable annual harvest from a fully regulated forest is f(t*)/t*. This quantity actually decreases with a price increase (Clark 1976), but the usual positive long-run reaction is obtained in most cases if management intensity is treated as endogenous (Hyde 1980, Chang 1983; also Williams & Nautiyal 1990).

The assumption of time invariant stumpage prices, costs, interest and tax rates is restrictive. When, for example, a change in the stumpage price is observed, the new price level is assumed to prevail through the entire future. As changes in exogenous factors can only be treated as permanent, one-time changes, the short-run supply reactions to the short-term fluctuation in prices, tax rates, etc. cannot be considered. However, the assumption can be relaxed by distinguishing

[*)] Superscript numerals in the text are references to Notes at the end of the chapter.

between the initial standing timber and the subsequent rotations (Johansson & Löfgren 1985, Ovaskainen 1987b). Then, the current stumpage price can differ from the expected long-run price level, or vary continuously with time (Hyde 1980, Newman *et al.* 1985, Johansson & Löfgren 1985).[2]

In addition to the rotation length, the yield from subsequent stands can be made to depend on management intensity (Hyde 1980, Chang 1983). Maximizing the present value of the standing timber plus net receipts from the subsequent rotations provides the same basic intuition as before, with the modification that the relative rate of value increment reflects not only physical growth but also the price change. Supposing the stumpage price follows a specific time path, the changes in the stumpage price can be broken into two parameters (Hyde 1980, Newman *et al.* 1985), one of which captures shifts in its initial level, while the other represents the rate of a continuing price change (i.e., a long-term trend).[3]

Two drawbacks still remain. First, the model's main decision variable is stand age, so timber supply – the desired harvest in a given period – is only implicitly dealt with. Furthermore, the optimal harvest age for the standing timber would only be obtained by a two-step procedure (first solving for the optimal rotation length and management intensity for the future rotations). Even then, short or long-run supply responses are only indirectly determined (see Ovaskainen 1987b). Secondly, neither of the two parameters representing the stumpage price can appropriately capture short-run price fluctuations. A discrete change in the initial price level, similarly to the one-time changes in the basic model, has to be treated as permanent. On the other hand, a continuing price trend at a steady rate cannot possibly represent short-run fluctuations. The point with respect to the present investigation is that in the continuous time model, considering the timing effects of taxes would be more difficult and has not been done so far. As with short-run price responses, the timing effects refer to *temporary* changes in the current tax rate compared to its expected future value.

2.1.2 The two-period model

The discrete time two-period model has major advantages for the present purpose. First, it represents the nonindustrial private forest owner's short-run decision problem in a conceptually sound and intuitively appealing manner. Short-run timber supply deals with the optimal harvest timing, given an arbitrary "inherited" stock of mature timber (cf. "stock supply" in Duerr 1960). Accordingly, short-run supply responses refer to the adjustment period before reaching the new optimum stock (Clark 1976, Hyde 1980). This is exactly what is considered in the two-period model, where the problem is how much to cut today and how much to leave for the future. As all future periods are lumped together, the approach represents *adaptive* decision-making: the decision is revised every period in the light of the most recent information on stumpage prices, costs, interest rates, and timber inventory.[4]

Secondly, the two-period model explicitly deals with timber supply (the desired harvest volume in a given period), rather than some state variable such as stand age. Thirdly, unlike the standard continuous time models, it is not limited to one-time changes or long-term trends in the exogenous variables, but allows for their short-run fluctuations. Thus, both temporary and permanent changes in the current stumpage price or tax rate can be dealt with, as well as their anticipated future changes (the latter have to do with the transitional effects of an announced switch between tax bases). Fourth, the model is technically simple and open to generalizations. For example, it can easily deal with various "imperfections" in the capital market (e.g. Lohmander 1983, Koskela 1989b, Kuuluvainen 1990); in the rotation model, this would call for a major revision of the modelling strategy, since present values are not well-defined. While not an issue for this study, such things may matter when modelling NIPF owners' short-run behavior for empirical purposes (e.g. Kuuluvainen 1989). Also, the results can be taken to represent both thinnings, uneven-aged management, and even-aged management with clearcutting (see section 3.1). This differs from the standard rotation model, which deals with an even-aged stand and clearcutting.

The two-period model also has significant shortcomings as regards the applications presented so far. First, the only decision variable has been harvest timing for a given stock of timber. Consequently, the concept of "timber supply" is identical to the *current harvest* or short-run supply. This notion may be too narrow for the evaluation of forest taxes. For example, seeking to elicit a maximal timber supply subject to a tax revenue target then results in maximizing the current harvest without properly recognizing the reduction in the future harvest. Secondly, while silvicultural measures actually are of importance to timber production over time, forest growth has been taken to be determined by a given soil productivity alone. Thus, the two-period model calls for extensions to allow for the management intensity decisions and implications on long-run timber supply. Thirdly, land rent considerations have been ignored. It will be shown below how a counterpart of the land rent factor could be incorporated.

2.1.3 Modelling stochastic elements

Future stumpage prices, real interest rates and forest growth may involve varied degrees of uncertainty. A number of modelling approaches have been suggested to deal with risk situations, where the uncertain outcomes are assumed to have a known mean and probability distribution. Several studies have incorporated stochastic elements into the optimal rotation model. Reed (1984), for example, incorporated the risk from wildfire. Applications of the optimal stopping approach to resource management include Clarke & Reed (1989) and Reed & Clarke (1990). Optimal harvest rules are derived for biological assets with stochastic age-dependent (1989) as well as size-dependent (1990) growth and stochastic prices. Timber harvesting decisions with stochastic future prices are also considered by Brazee & Mendelsohn (1988) and Haight (1990), who both use reservation prices to derive the optimal stopping rule (with the current price above the reservation price, the stand should be cut, otherwise one should wait).

The above studies (except Clarke & Reed 1989) have assumed risk neutrality, whereby decisions are based on the expected present value (mean of the probability distribution). However, economic theory suggests that people are more likely to be risk averse, and a number of attempts have been made to incorporate risk aversion into the management decision.

Formally, risk aversion is defined by the strict concavity of the utility function (diminishing marginal utility with respect to income). Thus, the two-period model of consumption and savings offers a natural way to incorporate uncertainty and risk aversion in terms of the expected utility hypothesis. Using this approach, Koskela (1989a,b) analyzed the effects of price uncertainty on the timber supply decisions. Under perfect capital markets and certainty, the harvesting decision is independent of the consumption decision. In contrast, where future price uncertainty and risk aversion are present, the harvesting decision depends on the forest owner's consumption preferences. Thus, harvesting and consumption decisions must be considered simultaneously (a similar nonseparability is implied by capital market "imperfections" such as credit rationing). The current harvest will increase compared to the case of certainty. Ollikainen (1990) considers the effect of interest rate uncertainty, showing that lenders tend to decrease and borrowers increase their current harvest.

On the other hand, other approaches have been developed which employ the expected value and higher moments of the distribution of returns. The best known of these criteria is the mean-variance rule, which is valid for quadratic or exponential utility functions or, irrespective of the form of utility function, for returns with a specific random pattern (e.g. Samuelson 1970, Newbery & Stiglitz 1981). Caulfield (1988) incorporates risk aversion into the rotation decision under the risk of wildfire by using stochastic dominance analysis, where an explicit assessment of the utility function is not required.

2.2 Effects of forest taxation and nontimber objectives

2.2.1 Harvesting, management intensity, and taxation

Earlier work on taxation and forests is mainly based on the optimum rotation model (e.g. Klemperer 1976, 1982, 1983, Jackson 1980, Chang 1982, 1983). It concentrates on the impacts of annual property taxes (the unmodified *ad valorem* property tax on the value of timber plus land, site value tax, and timber tax) vs. harvest taxes levied on the realized stumpage income (the percentage yield tax, and the severance or unit tax).

Considering the rotation age alone, the qualitative main result is that yield taxes tend to extend rotations, while property taxes tend to shorten them (e.g. Chang 1982). Chang (1983) extends the tax analysis to cover the effects on management intensity. The effect of an *ad valorem* property tax is equivalent to an increase in the interest rate by the tax per cent. In one case, it can be shown to reduce both the optimal planting density and rotation age. Otherwise the results remain ambiguous, which is due to the generally undetermined sign of the interaction effect between the management intensity and rotation length. The *site value tax* leaves both planting density and rotation age unaltered in all cases. Its neutrality is of interest since the site value tax is in effect similar to the "unmodified" site productivity tax, both representing lump-sum taxes. The *yield tax* on the stumpage value at harvest is equivalent to a reduction in the stumpage price by the tax per cent. It lengthens the optimal rotation and lowers the planting density in some cases, but in another case its effect remains uncertain.

It may be noted that the results from rotation models are based on the assumptions of perfect capital markets and certainty. These are required for the maximization of present value to be a well-defined objective, i.e., for the implicitly assumed separability of consumption and harvesting decisions to hold (e.g. Hirshleifer 1958, 1970). Also, the effects are stated in terms of rotation age rather than optimal harvest volume, so the implications on short and long-run timber supply are only implicitly determined.

Koskela (1989a) analyzes timber supply and forest taxation (lump-sum, yield, and unit taxes) under future price uncertainty and risk aversion using a two-period model of consumption, savings, and timber harvesting. In Koskela (1989b), capital market "imperfections" are also included. Along with the nonseparability of harvesting and consumption decisions, the impacts of forest taxes differ sharply from those under perfect capital markets and certainty. In addition to the substitution effects, taxes now have wealth effects. Consequently, even in the case of perfect capital markets (Koskela 1989a), lump-sum taxes are nonneutral and the effects of yield taxes remain ambiguous as the substitution and wealth effects run counter to each other. The future yield tax also has a risk effect. Under credit rationed capital markets (Koskela 1989b), the wealth effects are replaced by liquidity effects. In Ollikainen (1990), forest taxation is similarly considered under an uncertain real interest rate and perfect vs. imperfect capital markets. Ollikainen (1991) analyzes lump-sum, exogenous labor income and capital income taxes under price uncertainty, showing that the entire tax system may affect timber supply decisions. The capital income tax is of special importance because, as will be shown below, its effect does not depend on the presence of any imperfections or uncertainty, but appears even in the separation case.

Besides the *ceteris paribus* effects of individual forest taxes, the studies by Koskela and Ollikainen also consider the effects of compensated switches between forest taxes which keep the present value of the total tax revenue unchanged. The latter results are partially undermined by the concept of timber supply in this type of model. As timber supply refers to the harvest timing problem (i.e., short-run supply), analyzing the relative effectiveness of forest taxes by searching for the tax regime with the highest timber supply amounts to maximizing the current harvest. As this can only take place at the cost of reducing the future harvest, such a policy is unlikely to be pursued as a general goal. More basically, the criterion of effectiveness, defined in this way, is not guaranteed to be consistent with the standard efficiency measure (excess burden) of taxation. At least, a wider concept of timber supply should be applied.

In Vehkamäki (1986), the effects of several forest taxes on the equilibrium growing stock and silviculture are considered using an optimal control model. The cases include, first, two types of progressive income taxes. A tax on the "pure income" from forestry (i.e., a site productivity tax) is neutral as long as the tax rate is not so high that forest ownership decisions are affected. A progressive tax on the realized sales income reduces the equilibrium harvest and forest investments where the interaction between the growing stock and silviculture is positive. Secondly, a tax imposed on the stocks in forestry is examined. This has a dual nature, as both a property tax on the growing stock and a "payroll tax" on forestry investments. The investments in silviculture are reduced, while the effect on the equilibrium growing stock depends on the direction of stumpage price change. Thirdly, non-progressive harvest or realized income taxes are analyzed. A proportional, or *ad valorem*, sales tax reduces silviculture, equilibrium stock and harvest. A unit sales tax, on the other hand, will reduce the silvicultural investments while its effect on the equilibrium stock depends on the price change. Note that the results refer to what can be called the long-run, steady state timber supply (equal to growth at the optimal stock and management intensity). The formulation is less suitable for the study of short-term reactions to fluctuations in the tax rate or expected tax switches. Also, the economic efficiency of taxes is not explicitly considered.

Gamponia & Mendelsohn (1987) examine the relative efficiency of forest taxes by measuring the magnitude of the rotation age distortions caused by property and yield taxes. The paper makes a contribution with regard to both substantive results and the method of comparison. First, to compare the efficiency of any two taxes, the tax rates are set to raise the same present value of tax revenue. Secondly, *excess burden*, i.e. the present value of income lost for tax-induced distortions, is established as the appropriate measure of the relative efficiency of forest taxes. Finally, the magnitude of the distortions, or reduction in gross income caused by each tax, is measured in quantitative terms. The results from a numerical simulation suggest that yield taxes outperform property taxes, but there is only a small quantitative advantage.

The analysis by Gamponia and Mendelsohn, however, is not without limitations. First, it is based on the (explicit) assumption that the rest of the economy is distortion free. As no management distortions pre-exist, minimizing the excess burden simply implies choosing a combination of yield and property taxes so as to neutralize the distortions from forest taxes. Alternatively, a single neutral tax could be used, such as the site value or productivity taxes. However, the desirability of neutral forest taxes only holds if any distortions from other taxes do not pre-exist. Where they do, the efficiency effects of forest and other taxes should be simultaneously considered (cf. Rosen 1985, p. 286). As Kovenock (1986, p. 202) puts it, neutrality, unless defined with respect to a complete tax system, may not be an appropriate goal of tax policy. When tax distortions already exist, a non-neutral tax in any given sector may prove more efficient than a neutral tax, if it is properly designed to correct the initial inefficiency. Secondly, their definition of excess burden refers only to the income lost, i.e., *reduction* in output. Generally, excess burden is the loss in individual utility beyond that caused by the given amount of income collected as (lump sum) tax revenue, and follows from *any* distortion of an efficient allocation. Thus, even a subsidy generates an excess burden although the output is increased (e.g. Rosen 1985, p. 287; Auerbach 1985, p. 67–69). Also, only rotation age distortions are considered, while the analysis of changes in management intensity remains to be done.

Kovenock & Rothschild (1983) examine the efficiency of a capital gains tax in an economy with an "Austrian sector" and an ordinary sector (standard examples of Austrian assets are trees and wine, while the ordinary sector is defined as a sector that yields a constant stream of returns on resources invested therein). Capital gains taxes are only imposed on Austrian assets.

First, the *intersectoral* allocation of investment is efficient when the marginal rate of (social and private) returns on funds invested is the same in all sectors. If there is a tax in the ordinary sector, and no taxes in the Austrian sector, resources invested in the ordinary sector have a higher marginal social rate of return than those in the Austrian sector. Consequently, too much capital will be tied to the Austrian sector, and moving resources from the Austrian to the ordinary sector would imply an efficiency gain. Secondly, there is the problem of allocation *within a sector*. For Austrian investments, the allocation is optimal when trees, for example, are cut down at the time which maximizes the discounted social value of the resource. That is, the marginal rate of value increment should equal the social discount rate. If the ordinary sector is taxed by an income tax while the Austrian sector is not, assets such as timber will be held too long. In other words, there is a lock-in effect in the absence of capital gains taxation on Austrian investments.

Kovenock and Rothschild consider both capital gains taxes levied on a *realization* basis (due when the asset is sold) and those levied on an *accrual* basis (whenever an asset's market value changes). A capital gains tax on either basis drives resources from the Austrian sector and increases the marginal rate of return on such assets. However, especially the effect on the selling time of timber depends on whether an accrual or realization basis is chosen. In most cases, the higher the capital gains tax rate the sooner the asset is sold. This holds, for example, for timber taxed on an accrual basis (cf. accrual income or *ad valorem* property taxes). An exception is timber taxed on a realization basis (cf. harvest or yield taxes). In that case, the selling time of timber is independent of the tax rate and longer than it should be.

Kovenock (1986) examines the effects of property and income taxation in a similar setting and shows that a property tax is appropriate for the Austrian sector. When the ordinary sector is subject to an income tax, a property tax on the market value of Austrian assets allows the economy to achieve production efficiency (note that the market value of "land" includes the value of the timber). A property tax levied in the Austrian sector at a properly chosen rate – equal to the social discount rate multiplied by the income tax rate in the ordinary sector – attains both inter and intrasectoral efficiency. Property taxation at this rate is shown to be equivalent to an *accrual* income tax at a rate equal to the income tax in the ordinary sector. In the latter case, income is defined as the sum of realized cash returns and the change in the asset's market value (i.e., an increase in the standing stock is also taxed). On the other hand, Kovenock shows that a *realized* income tax with immediate expensing in the Austrian sector is inconsistent with production efficiency.

Property taxes, when based on the market value of the timber, tend to shorten timber rotations. This nonneutrality has been much criticized in the U.S. forest tax debate (for a survey, see Boyd 1986). However, part of their "bad reputation" (Klemperer 1977) might be explained by the assumption of no pre-existing distortions which has often been implicit in the discussion. Even Gamponia & Mendelsohn's (1987) analysis, correct as such, explicitly shares this presumption. As the assumption is unlikely to hold in real economies, the policy implications tend to be misleading. As a notable exception, Kovenock (1986) duly recognizes that the neutrality of taxation must be considered in terms of the entire tax system (a similar idea can be found in Chisholm 1975). Accordingly, a realized income tax on forestry, even if neutral as such, will generate a lock-in effect on timber harvesting when combined with a tax on the interest from other assets. In contrast to most of the earlier discussion, an *ad valorem* property tax is in fact shown to attain efficiency under such circumstances.

Kovenock (1986) provides a major contribution in terms of both analytic insight and relevance to policy issues. It can be noted that Kovenock's approach represents a partial solution with respect to production efficiency in the Austrian sector, *given* an income tax in the ordinary sector. Despite the theoretical limitation, it seems reasonable – with an eye on implications to forest taxation – to follow this approach in the present study (for more detail, see section 5.1). On the other hand, limitations in the scope of Kovenock's study suggest some useful extensions. First, management intensity is not considered and timber supply consequences are not directly shown. Secondly, one may ask if the conclusions are sensitive to the assumptions on the decision-maker's objective function. An obvious example is the inclusion of the forest's nontimber services, which are commonly taken to be positively related to the standing stock of timber.

2.2.2 *Timber harvesting with nontimber benefits*

Besides commercial timber at harvest, the standing forest also provides a flow of benefits such as scenic beauty, recreation, wildlife, berries and mushrooms, and watershed control. The flow of nontimber services – the scenic or recreational value of a forest, for example – apparently depends on the age of the trees. Therefore, such considerations may matter for the harvesting decision that alters the size and age structure of a forest's standing stock. There are two main lines of modeling this relationship in the literature.

As a generalization of the Faustmann model, the influence of age dependent nontimber services was first considered by Hartman (1976) and Strang (1983). They suggested that the socially optimal rotation age with nontimber values added exceeds the commercial rotation and, in the polar case, the forest may never be cut. However, the result depends on the assumption that the flow of nontimber services is monotonically increasing with respect to stand age. As noted by Bowes & Krutilla (1985) or Hite *et al.* (1987), there is no *a priori* reason for this to be the case, as a varied mix of services is represented. Rather, the socially optimal rotation will be longer (shorter) than the commercial rotation as the amenity value is monotonically increasing (decreasing) in stand age. The problem has also been considered as an extension to the linear forest model by Berck and Bible (1984) and Johansson *et al.* (1989). In an economy with forest owners deriving utility from commercial timber only, and a public "consuming" environmental services, Johansson *et al.* present a Pareto optimal system of shadow prices for amenity services. Then, the optimal "multiple-use" harvest policy can be solved from a present value problem augmented by the shadow prices for environmental services from each age class (also, Johansson & Löfgren 1988).

The approach is restrictive because, first, the additivity of commercial and nonharvest values presupposes that the harvesting and consumption decisions are made independently. Where the imputed utility from unpriced amenity values is taken into account, this is not generally true, even if the capital markets are perfect (Hite *et al.* 1987, Johansson & Löfgren 1988, Ovaskainen 1989). Secondly, to maximize the sum of harvest income and nontimber services, the nontimber benefits must be measurable in monetary terms; and while possible to estimate in principle (e.g. Cummings *et al.* 1986, Johansson 1987), money measures are not actually known. Thirdly, there is no way for the forest owner to be compensated for providing nontimber services, which usually are nonmarketed public goods. Thus, there is no "external" incentive to follow the optimal plan, even if the shadow prices were known.

An alternative approach has been used by e.g. Binkley (1981, 1987), Kuuluvainen (1985, 1986) or Max & Lehman (1988). The nontimber services are taken to be an increasing function of the volume of the standing stock. This function or, assuming proportionality for simplicity, the standing stock itself, is substituted directly into the forest owner's utility function.[5] A basic implication is that the nontimber considerations will reduce the current harvest, since a larger stock is desired if the environmental value is monotonically increasing in the standing volume.

There seems to be an advantage in explicitly treating the nontimber services as nonmarketed, nonpriced benefits, because this serves to highlight the fact that given no actual compensation, it depends on the forest owner's subjective preferences whether or not the scenic or recreational values will be taken into account. However, as is the case with the rotation model, the shape of the flow of amenities should be established in the light of empirical findings (see Chapter 6). Also, the harvest change is just a short-run reaction. Up to a certain limit, a larger growing stock implies an increase in the sustainable harvest over time. Further, the earlier analyses were static, involving a single period only, or, in the multiperiod case, implicitly assumed that the forest owner has no access to the capital market. The two-period model by Max & Lehman (1988) adds the intertemporal aspect, but retains the implicit autarchy assumption.

In Hyberg & Holthausen (1989), the harvest timing and reforestation decision is modelled as a multiperiod utility maximizing problem with the imputed utility from nontimber benefits included in the objective. The model involves (perfect) capital markets and a growth function dependent on stand age and reforestation intensity. Some implications are that "utility maximizers" harvest less often and invest more in reforestation than do "profit maximizers". Forestry incentive programs may subsidize the consumption of nonmarket forest amenities but have limited effect on timber production. Due to the model's increased complexity, however, all comparative statics results remain uncertain unless the interaction between the choice variables is excluded. Further, the extended rotations are dictated by the assumption that the amenity value is monotonically increasing in stand age and volume.

Few papers have dealt with forest taxation in the presence of nontimber services. Max & Lehman (1988) consider *ad valorem* property, yield, severance, and site productivity taxes using a two-period model. The impacts of yield, severance, and site taxes remain indeterminate, as the substitution effects work in the opposite direction to the income effects. The only unambiguous result is for the property tax, which increases the current harvest (i.e., both effects work in the same direction). Englin & Klan (1990) investigate the impacts of timber taxation on the production of external nontimber benefits using an optimal rotation model. When nontimber benefits are public goods, the private forest owner's failure to take them into account leads to a divergence between social and private rotation periods. Accordingly, the study searches for potential "pigouvian taxes" (after Pigou 1920), i.e. tax regimes that induce the private landowner to behave in a socially optimal manner. Pigouvian tax formulas are presented for harvest taxes (the yield, severance or unit, and profit tax) and for a property tax levied on the value of timber. The results suggest that the "optimal" tax rates depend on several factors, and are difficult to determine in practice.

2.3 Conclusion

The motivation and objectives of the present study can now be specified in more detail (for numbering, compare section 1.2). The preceding review pointed out that the effects of forest taxes are rather well understood – and their relative efficiency can be analyzed – in terms of rotation age and management intensity. However, it is considered useful to explicitly analyze forest taxation in terms of timber supply, which is the ultimate point of practical interest in the issue.

(1) For this purpose, the discrete time two-period model is preferred to the optimal rotation model as an analytically more convenient approach. To overcome the limitations of its earlier versions, the model is first extended by incorporating the management intensity as a choice variable. Secondly, the notion of long-run steady state timber supply is derived. Conceptually, the long-run timber supply refers to the sustainable harvest per period, constrained by the forest's mean increment. In other words, the long run implies a time span long enough for the timber stock to equilibrate at the optimal level (Clark 1976, Hyde 1980, Binkley 1987) and for the management intensity decisions to be realized in timber production. Theoretically, the short and long-run solutions will be shown to be consistent with the well-examined continuous time optimal control models for renewable resources.

(2) For the positive analysis of forest taxation, two novelties are provided. Contrary to the optimal rotation-based literature, the effects of forest taxes are explicitly considered in terms of timber supply. Unlike earlier two-period models, the analysis covers the management intensity decision and long-run timber supply in addition to the short-run harvesting decision (i.e., the permanent effects of taxes). Also, the chosen framework allows the nontimber services of a forest to be incorporated in an intuitive manner as unpriced benefits.

(3) The study's main focus is on the normative analysis or relative efficiency of forest taxes, which is less well understood. Note that the criterion of *economic efficiency* should be distinguished from what might be called the *effectiveness* of a policy. The latter refers to the "power" of alternative instruments in achieving a given policy goal or desired behavioral change (i.e., some effect/input ratio), while the efficiency criterion can be taken to deal with the more fundamental issue of the "economic justification" or desirability of policy goals. Two aspects are stressed.

As a conceptual point of departure, first, the correct efficiency criterion is the *excess burden* of taxation at any given level of tax revenue. Specific counterparts to this general notion for various situations will be developed below. Secondly, whether neutral or nonneutral forest taxes are "optimal" depends on whether distortions due to other taxes or sectors pre-exist. Assuming an initially undistorted economy, efficiency is shown to be met by neutral forest taxes. Where tax distortions pre-exist, the effects of forest and other relevant taxes must be considered as a whole, and a nonneutral forest tax may be needed to offset the initial distortion. That is, neutrality is an appropriate objective only when defined with respect to the entire tax system. As an important example of pre-existing management distortions, the effects of capital income taxation are considered. The tax analysis is elaborated by incorporating benefits other than commercial timber in order to examine the sensitivity of the conclusions with respect to the forest owners' and/or policy-maker's objectives.

(4) While "pure", stylized forest tax regimes have usually been analyzed in the literature, actual forest tax systems may be rather more complicated. In Finland, a specific form of the site productivity taxation has been applied. Involving tax exemptions for regeneration areas and seedling stands, as well as deductions for major management costs, the system is far removed from an unmodified, lump-sum productivity tax. The present study will analyze the effects of this tax system and evaluate the efficiency of the recent reform. This is of direct practical interest and has not been done before. Conceptually, it is important to note that excess burden is not only generated by a reduction in output, but follows from *any* distortion of an efficient allocation (thus, even a subsidy or a subsidy-like tax exemption may generate an excess burden).

On the other hand, the evaluation of realized income taxes under capital income taxation directly bears on the current reform of forest and other capital income taxation in Finland (Pääomatulojen … 1991). While the effects of capital income taxation in general should matter for the choice of an efficient forest tax regime, this point has been ignored in the proposals introducing a realized income tax on forestry (Puukaupan … 1989, Pääomatulojen … 1991, Puun myyntitulojen … 1992). As shown by Kovenock (1986), a realized income tax creates a lock-in effect on the realization of timber when combined with a tax on other assets (deductibility of interest charges). The theoretical point is further clarified, and numerical examples are provided to illustrate the magnitude of the implied management distortions.

Finally, while capital market "imperfections" and the uncertainty (risk) associated with future prices or forest growth are important topics in recent research, the present study will abstract from such issues. A detailed analysis of lump-sum and yield taxes under an uncertain future price or interest rate and credit rationing can be found in Koskela (1989a,b) and Ollikainen (1990, 1991). In the present context, incorporating imperfections or uncertainty would unduly complicate the analysis. As the present study will focus on the relative efficiency of alternative forest taxes, only their substitution effects are of importance. That is, the wealth and liquidity effects arising from stochastic prices and credit rationing, for example, are irrelevant (see section 3.1).

Notes to Chapter 2

[1]Denoting the land expectation value by LEV, the problem in the basic rotation model (the Faustmann formula) can be written as

$$\underset{\{t\}}{\text{Max}}\ LEV = \left[pf(t)e^{-rt} - C\right]/\left[1 - e^{-rt}\right],$$

where p = stumpage price, f(t) = timber volume as a function of stand age ($f' > 0$, $f'' < 0$), r = rate of interest in the perfect capital market, and C = regeneration cost. The first-order condition $pf'(t) - rpf(t) - rLEV(t) = 0$ can be rewritten as

$$pf'(t)/\left[pf(t) - C\right] = r/\left[1 - e^{-rt}\right],$$

i.e., the relative rate of value growth equals the discount rate corrected by $[1 - e^{-rt}]^{-1}$.

[2]Brazee & Mendelsohn (1988) incorporate stochastic short-run price fluctuations in a similar formulation.

[3]The maximization of the present value of the standing timber plus net receipts from the subsequent rotations, denoted PV, can be written as

$$\underset{\{a,t,m\}}{\text{Max}}\ PV = \left\{p(a)f(a) + LEV(t,m)\right\}e^{-r(a-b)},$$

where a denotes the harvest age (time) for the standing timber and b is its initial age, while p(a) and f(a) are its stumpage price and timber volume as functions of harvest time. Further, $LEV(t,m) = [pf(t,m)e^{-rt} - wm]/[1 - e^{-rt}]$, where p = the constant stumpage price for the subsequent rotations, f(t,m) is their yield as a function of rotation length t and management intensity m, and w = unit cost of inputs. Solving first the optimal t and m for the future rotations, the optimal harvest age for the standing timber can be solved by substituting the optimal values t^* and m^* into the objective function. Rearranging,

$$f'(a)/f(a) = [r - p'(a)/p(a)] + r\,LEV(t^*,m^*)/p(a)f(a).$$

If the stumpage price follows the path $p(a) = p_0e^{\rho(a-b)}$ with $p_0 = p(b)$, $p'(a)/p(a) = \rho$, then p_0 captures shifts in the initial price level while ρ represents the rate of a continuing price change (trend).

[4]This holds excluding a corner solution where all timber is cut in the first period. The same basic intuition underlies the adaptive optimization or optimal stopping approach, using reservation prices, to resource management in a stochastic environment (see section 2.1.3).

[5]In other words, the forest owner himself is assumed to derive utility from the nontimber services. Contrary to the implication by Englin and Klan (1990), this assumption need not suggest that the public is excluded from the use of the environmental services. Indeed, they may be institutionalized as public goods by the so-called everyman's rights ("allemansrätt"), as in Scandinavia.

3 A model of timber supply

This chapter develops the theoretical model which is to be used as an analytic tool in the study. As discussed in Chapter 2, the discrete time two-period model is an appropriate point of departure but two extensions need to be made. Section 3.1 introduces the formulation, with management intensity incorporated as an additional choice variable, and discusses the basic assumptions. The solution and comparative statics results for the short-run timber supply and management intensity decisions are established in section 3.2. The long-run steady state timber supply and its properties are developed in section 3.3. In section 3.4, additional notes are made concerning the properties of the model.

3.1 Formulation and assumptions

In the actual analysis of forest taxation and timber supply, a two-period model will be used. Initially, however, a *three-period* setting is considered. This way of presentation serves to establish the validity of the two-period model with respect to short-run timber supply (the first-period harvest is unaffected by the number of periods). On the other hand, the three-period setting is used to derive the long-run timber supply, which is conceptually met by the second-period harvest in a three-period model. It is shown that even the long-run effects can be analyzed by using the results from a two-period model.

Objective function and budget constraints

Suppose the forest owner behaves as if he/she maximized the utility of consumption over three periods. Following e.g. Koskela (1989a,b), let the forest owner's preferences with respect to consumption be represented by the intertemporally additive separable utility function U,

$$U = u(c_1) + \beta u(c_2) + \beta^2 u(c_3). \tag{3.1}$$

In (3.1), c_i is consumption in period i (i=1,2,3) and $\beta = (1 + \rho)^{-1}$, where $\rho > 0$ is the forest owner's subjective rate of time preference (Atkinson & Stiglitz 1980, Olson & Bailey 1981). Further, a positive but diminishing marginal utility of consumption is assumed, i.e., $u'(.) > 0$ and $u''(.) < 0$.

In what follows, H_i is used to denote the desired volume of timber harvested or timber supply in period i, E_i denotes management intensity (silvicultural effort), and S_i is net savings (saving as $S > 0$ and borrowing as $S < 0$). Further, p_i is the stumpage price, w_i is the unit cost of silvicultural inputs, and r is the market rate of interest (constant for all periods). First-period consumption possibilities, constrained by the revenue from timber sales minus net saving and investment in silviculture, can then be written as

$$c_1 = p_1H_1 - S_1 - w_1E_1. \tag{3.2}$$

The second-period consumption is constrained by the sum of harvest revenue and past savings with the interest minus that period's saving and forest management costs,

$$c_2 = p_2H_2 + (1 + r)S_1 - S_2 - w_2E_2. \tag{3.3}$$

The third period is the terminal point of the time horizon, during which no savings or productive investment are made. Thus, all the revenue from timber sales, as well as all past savings and interest, can be consumed, or

$$c_3 = p_3H_3 + (1 + r)S_2. \tag{3.4}$$

Next, define the relevant constraints for each period's harvest, H_i, and the expressions for the growing stock K_i that remains after the harvest in the beginning of each period. Let Q denote the exogenously given initial stock of timber, while $F = F(K,E)$ is forest growth as a function of the growing stock and management intensity. The harvest constraints for periods 1 through 3 (excluding corner solutions) are

$$\begin{aligned} &H_1 < Q \\ &H_2 < K_1 + F(K_1,E_1) \\ &H_3 = K_2 + F(K_2,E_2), \end{aligned} \tag{3.5}$$

and the respective expressions for the post-harvest growing stock K_i are defined as

$$\begin{aligned} K_1 &= Q - H_1 > 0 \\ K_2 &= Q - H_1 + F(Q - H_1,E_1) - H_2 > 0 \\ K_3 &= Q - H_1 + F(Q - H_1,E_1) - H_2 \\ &\quad + F[Q - H_1 + F(Q - H_1,E_1) - H_2, E_2] - H_3 = 0. \end{aligned} \tag{3.6}$$

As the first and second-period harvest constraints are nonbinding, H_1 and H_2 will be true choice variables. In the terminal period, the whole inventory and increment inherited from period 2 will be cut, since the standing stock itself is not assumed to impute utility (cf. Chapter 6). Thus, the third-period harvest constraint will be binding and can be substituted into the budget constraint to eliminate H_3. Solving first (3.2) for S_1 and substituting into (3.3), S_1 can be eliminated. Solving in turn (3.3) for S_2 and substituting into (3.4), S_2 can also be eliminated. Besides S_2, the equation for H_3 defined in (3.5) and (3.6) will be substituted into (3.4) to write the intertemporal budget constraint. By finally substituting the resulting expression for c_3 into the objective function, c_3 is eliminated, and the problem becomes

$$\underset{\{c_1,c_2,H_1,\ H_2,E_1,E_2\}}{\text{Maximize}}\ U = u(c_1) + \beta u(c_2) + \beta^2 u(c_3), \tag{3.7}$$

where

$$c_3 = p_3 \{Q - H_1 + F(Q - H_1,E_1) - H_2 + F[Q - H_1 + F(Q - H_1,E_1) - H_2, E_2]\} + (1 + r)[p_2H_2 + (1 + r)(p_1H_1 - w_1E_1 - c_1) - w_2E_2 - c_2].$$

In other words, the choice variables of the problem are first and second-period consumption, harvest, and management intensity. Before going into the formal solution of the optimization problem and its implications, it is useful to discuss some assumptions of the model.

Properties of the growth function

The growth function $F = F(K,E)$ is assumed to be twice continuously differentiable with

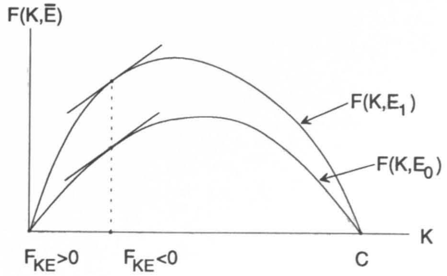

Fig. 1. The effect of management intensity ($E_1 > E_0$) on forest growth and marginal product of growing stock: K and E initially complementary, subsequently competitive.

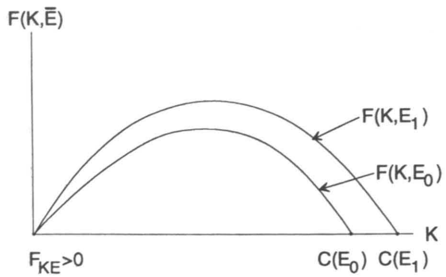

Fig. 2. The effect of management intensity ($E_1 > E_0$) when the growing stock and management intensity are complements for all relevant values of K.

the following properties:[1]

$$\begin{aligned} &F(.) > 0 \text{ for all } K \in (0, C),\ E \geq 0; \\ &F_K \geq 0 \text{ as } K \in (0, M],\ F_K < 0 \text{ as } K \in (M, C); \\ &F_E > 0,\ F_{KK},\ F_{EE} < 0 \text{ for all } K \in (0, C),\ E > 0; \\ &F_{KK}F_{EE} - (F_{KE})^2 > 0 \text{ over the relevant range.} \end{aligned} \tag{A.1}$$

In (A.1), M denotes the density of maximum sustained yield (MSY) at which $F_K = 0$. C is the carrying capacity of the site, i.e., the saturation stock at which the growth declines to zero (Fig.1). The assumptions in (A.1) imply, for example, that the growth rate first increases with the growing stock ($F_K > 0$) as the productive potential of the site is more fully utilized. Yet the marginal return on the growing stock, with E fixed, is diminishing so that the slope F_K declines and eventually becomes negative at $K > M$ due to increasing competition between the trees for sunlight, water, and nutrients. Similarly, the management intensity shows diminishing marginal returns, i.e., the additional gain becomes progressively smaller for each additional unit of inputs.[2] Following e.g. Hyde (1980), E is assumed to include all labor and capital inputs measured continuously in some standardized unit (kilos of fertilizer with the growing stock fixed, successively higher numbers of seedlings or man-machine hours given to site preparation per hectare, etc.). A fixed area of land, normalized to one, is implicit in the formulation.

The second-order cross-partial derivative of the growth function, $F_{KE}(.)$, requires special attention. This is because it turns out to be decisive for the interpretation of the results. The interaction effect measures the change in the marginal product of the growing stock as a result of changes in management intensity, or *vice versa*.[3] There is a difficulty that resembles the one pointed out by Chang (1983) with respect to the yield function in the generalized rotation model. In the general case, the sign of F_{KE} might depend on the location of the optimum so that no single sign can be postulated (Fig. 1). However, even if the interaction term can be positive, negative, or zero, it can be signed definitely for specific types of silvicultural measures. The following classification of distinct cases will suffice to interpret the results. (Mathematically, $F_{KE}(.) = F_{EK}(.)$ by Young's theorem. While only discussed in terms of F_{KE} for space, the real-world interpretations similarly go through in terms of F_{EK}).

(1) A positive interaction ($F_{KE} > 0$) is represented by measures such as fertilizing a thinned immature stand, an uneven-aged forest or a mature stand considered for clearcutting, as well as the drainage of well-stocked peatlands. Improvements such as fertilization or drainage compare to a higher site index. As the carrying capacity of the site increases, the stand will eventually reach a higher maximum volume (Chang 1984). The slope F_K thus increases for all relevant densities (Fig. 2).

(2) No stock-effort interactions arise ($F_{KE} = 0$) from the establishment of new stands on previously idle land (e.g. the afforestation of arable land or drainage of poorly stocked peatlands). Since such improvements are operationally independent of the cutting of any existing stands, the aggregate growth for the remaining old-growth plus the new stands could be written in the additive separable form $F(K,E) = f(Q - H_1) + g(E)$, which readily implies $F_{KE} = 0$ (E represents site preparation, planting density, etc. in the new stands;

f', f'' are similar to F_K and F_{KK} defined earlier, $g' > 0$, $g'' < 0$). Precommercial thinning and brush control, applied to stands with no harvestable timber, fall into the same category.

(3) A negative interaction ($F_{KE} < 0$) emerges when E is interpreted as reforestation measures subsequent to clearcutting or those for natural regeneration. Choices such as site preparation intensity, the age and quality of seedlings, planting density, or brush and vegetation control influence the growth of the subsequent stands.[4] The aggregate growth after clearcutting and replanting could be written as $F(Q - H_1,E) = f(Q - H_1) + g(H_1,E)$. Timber production in the subsequent stands depends on the current harvest and reforestation intensity ($g_H, g_E > 0$, $g_{HH}, g_{EE} < 0$). That is, via H_1 and E, respectively, g(.) recognizes both the number of hectares replanted (with constant returns to scale) and the amount of inputs used per hectare (with diminishing marginal returns). It can be shown that the term F_{KE} in the solution would be replaced by $-g_{HE} < 0$, so $F_{KE} < 0$ is a valid representation.[5]

The assumption of perfect capital markets

The assumption of "perfect capital markets" is employed throughout the study. In other words, there is one unique interest rate for both saving and borrowing, and no liquidity constraints due to quantitative limitations on borrowing are present. Also, perfect foresights (certainty) are assumed. While no claim is made that the assumptions are "realistic", the simplification is analytically appropriate and theoretically justified with respect to the purposes of this study. Its major implication is the separability of the productive decisions from consumption preferences. The analysis is much simplified, as the harvesting and management intensity decisions can be considered independently of consumption decisions. Further, taxes will only have substitution effects due to tax-induced changes in relative prices, while wealth or liquidity effects due to the implied reduction in disposable income do not appear.

On the other hand, the ultimate problem of the present study is the relative efficiency of forest taxes. The point is that only substitution effects represent inefficiency, while income effects do not (The Structure … 1978). The underlying theoretical argument is that the excess burden of taxation can be defined as the utility loss beyond the loss caused by the given amount of tax when collected as a lump sum (e.g. Rosen 1985). Given that lump-sum taxes have income effects only, excess burden is represented by the distortions beyond income effects, i.e., by substitution effects alone. That is why the income effects, and capital market "imperfections" or uncertainties that generate them, can be ignored here, even if they are likely to appear in reality. By the same logic, the income effects will be omitted in the normative analysis in Chapter 6, where they arise from the inclusion of the utility from nontimber benefits.

In other words, the income effects depend on the amount of taxes collected rather than the specific way they are levied. For a reasonable comparison between any two taxes, both must be set to collect an equal tax revenue. Considering switches between forest taxes with the total tax revenue unchanged, an increase in one tax implies an equal reduction in the other. Then, the wealth or liquidity effects of forest taxes due to uncertainty or credit rationing, respectively, cancel out (Koskela 1989a,b). This is why liquidity constraints, for example, do not change the effects of compensated tax switches (Koskela 1989b).

3.2 Short-run timber supply and management intensity

This section turns to the properties of the harvesting and management intensity decisions. An interior solution will be assumed throughout the study (for discussion, see section 3.3). Partially differentiating (3.7) with respect to all decision variables and setting the derivatives equal to zero, the following first-order conditions for a solution to the maximization problem are obtained:

$$
\begin{aligned}
&U_{c_1} = u'(c_1) - \beta^2 u'(c_3)(1+r)^2 = 0 \\
&U_{c_2} = u'(c_2) - \beta u'(c_3)(1+r) = 0 \\
&U_{H_1} = \beta^2 u'(c_3)\{-p_3[1+F_{K_1}(.)] \\
&\qquad [1+F_{K_2}(.)] + (1+r)^2 p_1\} = 0 \\
(3.8)\quad &U_{H_2} = \beta^2 u'(c_3)\{-p_3[1+F_{K_2}(.)] + (1+r)p_2\} = 0 \\
&U_{E_1} = \beta^2 u'(c_3)\{p_3[1+F_{K_2}(.)]F_{E_1}(.) \\
&\qquad -(1+r)^2 w_1\} = 0 \\
&U_{E_2} = \beta^2 u'(c_3)\{p_3 F_{E_2}(.) - (1+r)w_2\} = 0.
\end{aligned}
$$

Using the first two conditions, $U_{c_1} = U_{c_2} = 0$, the condition for first and second-period consumption is obtained as $u'(c_i)/\beta u'(c_{i+1}) = 1 + r$ $(i = 1,2)$, which is similar to the first-period consumption in any two-period model (e.g. Sandmo 1985). As regards the harvesting and management intensity decisions, the conditions $U_{H_1} = U_{H_2} = U_{E_1} = U_{E_2} = 0$ will hold if and only if the braced expressions {.} are zero, because β, $u'(c_i) > 0$ by assumption. This has an important implication: where perfect capital markets and certainty can be assumed and benefits other than timber do not matter, the harvesting and management intensity decisions are separable from the consumption decision. That is, the productive decisions are determined by relative prices irrespective of the forest owner's preferences and consumption plans (e.g. Koskela 1989a, Kuuluvainen 1989). Whatever the forest owner's desired temporal pattern of consumption, the highest consumption set is obtained by following the present value maximizing productive solution, while the most preferred consumption pattern can be attained by adjusting consumption possibilities between periods by borrowing and lending in the capital market (Hirshleifer 1958, 1970, Johansson & Löfgren 1985).[6]

By the separation result, the conditions for the optimal first and second-period harvest and management intensity decisions can be simplified as follows:

$$(3.9a)\quad -p_3[1+F_{K_1}(.)][(1+F_{K_2}(.)] + (1+r)^2 p_1 = 0$$

$$(3.9b)\quad -p_3[1+F_{K_2}(.)] + (1+r)p_2 = 0$$

$$(3.9c)\quad p_3[1+F_{K_2}(.)]F_{E_1}(.) - (1+r)^2 w_1 = 0$$

$$(3.9d)\quad p_3 F_{E_2}(.) - (1+r)w_2 = 0.$$

Condition (3.9b) implies $p_3[1 + F_{K_2}(.)] = (1 + r)p_2$. Substituting this into (3.9a), the condition for optimal first-period harvest simplifies to $p_2[1 + F_{K_1}(.)] = (1 + r)p_1$. In other words, at the optimum, the marginal revenue with respect to the current harvest (current price p_1) equals its marginal opportunity cost (the discounted value of the reduction in the future harvest), $p_2[1 + F_{K_1}(.)]/(1 + r)$. Using (3.9b) again, (3.9c) simplifies to $p_2 F_{E_1}(.)(1 + r)^{-1} = w_1$ for optimal first-period management intensity, which is equivalent to the condition (3.9d) for the second-period effort. That is, the marginal return on silvicultural inputs (discounted value of the marginal increase in forest growth) equals the marginal factor cost. It is obvious that, in principle, the results could be shown to hold for any arbitrary number of periods. Generalizing by induction and rearranging, the rules for optimal harvesting and management intensity decisions for all non-terminal periods ($i < N$) can be written as

$$(3.10a)\quad \frac{p_{i+1}}{p_i}[1+F_{K_i}(.)] = 1 + r \text{ for all } i \in [1, N-1]$$

$$(3.10b)\quad \frac{p_{i+1}}{w_i} F_{E_i}(.) = 1 + r \text{ for all } i \in [1, N-1],$$

where N denotes the relevant number of periods. Condition (3.10a) requires that the rate of increment in value growth due to the marginal unit of growing stock equals the opportunity cost of capital (the interest rate). In other words, the optimal cutting rule is that all forest stands (trees), for which $\frac{p_{i+1}}{p_i}[1 + F_{K_i}(.)] \le 1 + r$ (i.e., the marginal rate of return is less than or equal to the interest rate), should be cut. Similarly, investments in silviculture are made up to the point where the marginal rate of return equals the opportunity cost of capital. For the terminal period N, the model formally assumes that no investments are made and all timber is cut, i.e. $E_N = 0$, $H_N = K_{N-1} + F(K_{N-1},E_{N-1})$ so that $K_N = 0$.

Comparing the first-period cutting rule

$$(3.10')\quad \frac{p_2}{p_1}[1+F_{K_1}(.)] = 1 + r$$

with its counterpart from the two-period model (e.g. Koskela 1989a, Kuuluvainen 1989), an important conclusion can be drawn: the solution for short-run timber supply (first-period harvest) holds irrespective of the number of periods in the model. The same applies to the first-period management intensity decision, which is similar to the two-period model (Ovaskainen 1991). Consequently, the two-period model is valid for the analysis of short-run timber supply and management intensity decisions. This result will be utilized below to make the comparative statics analysis as simple as possible.

Properties of short-run timber supply

It was shown above that the current harvesting and management intensity decisions are independent of consumption preferences, future decisions, and the number of periods. Omitting time subscripts for notational simplicity, denote the short-run supply, current silvicultural effort and growing stock after the harvest by H, E, and K, respectively. Then, the current decision variables H and E can be analyzed in terms of only two simultaneous equations:

$$\text{(3.11a)} \quad -p_2[1+F_K(Q-H,E)] + (1+r)p_1 = 0$$

$$\text{(3.11b)} \quad p_2F_E(Q-H,E) - (1+r)w = 0.$$

Owing to the separation properties, the second-order conditions for a maximum also reduce to $D_1 = -p_2F_{KK} < 0$, $D_2 = D = p_2^2\,[F_{KK}F_{EE} - (F_{KE})^2] > 0$, where D and D_i (i = 1,2) denote the determinant of the Hessian matrix of second-order derivatives with respect to the endogenous variables and its principal minors. The conditions are always satisfied given the assumptions about the growth function in (A.1).

Next, consider how the optimal decisions depend on changes in the exogenous variables. The comparative statics results are obtained by totally differentiating (3.11a) and (3.11b) with respect to H, E and all exogenous variables, and using Cramer's rule (e.g. Chiang 1974). The comparative static partial derivatives with respect to any exogenous variable (k) will be denoted by a subscript, i.e., $\partial H^*/\partial k = H_k$ and $\partial E^*/\partial k = E_k$. The properties of the short-run timber supply are as follows (the arguments of F(.) are omitted):

$$\text{(3.12)} \quad \begin{aligned} H_{p_1} &= -D^{-1}(1+r)p_2F_{EE} > 0 \\ H_{p_2} &= D^{-1}p_2[(1+F_K)F_{EE} - F_EF_{KE}] \begin{smallmatrix}<0\\=?\end{smallmatrix} \\ &\quad \text{as } F_{KE} \overset{\geq}{<} 0 \\ H_r &= D^{-1}p_2[-p_1F_{EE} + wF_{KE}] \begin{smallmatrix}>0\\=?\end{smallmatrix} \text{ as } F_{KE} \overset{\geq}{<} 0 \\ H_w &= D^{-1}(1+r)p_2F_{KE} \gtreqless 0 \text{ as } F_{KE} \gtreqless 0 \\ H_Q &= D^{-1}D = 1. \end{aligned}$$

There are two kinds of effects involved in the comparative statics results: first, *direct effects* due to changes in the marginal revenue and cost of current harvest and, secondly, *indirect effects* due to changes in the optimal management intensity. As the latter ones emerge through the interaction term F_{KE} and depend on its sign, the type of silvicultural measures must be specified for definite conclusions. For thinning stands (or an uneven-aged forest), fertilization is about the only relevant consideration beyond harvesting, while regeneration measures are the typical form of management choices for mature stands considered for final cutting. Accordingly, the case $F_{KE} > 0$ is identified with timber supply from thinnings (or selective harvests), while $F_{KE} < 0$ is taken to represent supply from final fellings. In particular, the effects of the stumpage price and interest rate are discussed in some detail. This is because they prove to be comparable to the effects of some of the most common forest taxes.

Consider a *ceteris paribus* increase in the *current* stumpage price (i.e., an observed price change perceived as temporary). The short-run supply will unambiguously increase, since the marginal revenue of the current harvest rises with its marginal cost unchanged. With an increase in the *future* stumpage price, the current harvest tends to decrease as the marginal cost increases. However, there is another effect due to an increase in the optimal management intensity. With $F_{KE} > 0$ (fertilization and thinning in well-stocked immature stands), an increase in E implies an increase in the marginal product of the growing stock, and a higher stock is desired. Consequently, timber supply from thinning stands is reduced. The same is true for $F_{KE} = 0$ (precommercial thinnings, etc.), since the indirect effects vanishes. For $F_{KE} < 0$ (E represents reforestation intensity), the two effects work in the opposite direction. With an increase in E, the marginal product of the current standing stock decreases relative to that of subsequent stands. The optimal stock of old stands therefore decreases. As the positive indirect effect counteracts the negative direct one, the overall effect of increasing price expectations on the supply from final fellings remains ambiguous.

With a higher *interest rate*, the current harvest tends to increase owing to an increase in the opportunity cost of capital tied to the growing stock. But the opportunity cost of investments in silviculture increases, too. The weakening of incentives to fertilize stands – the case of $F_{KE} > 0$ – amplifies the reduction in desired growing stock by reducing its marginal product. Thus, timber supply from thinnings unambiguously increases. This also holds for $F_{KE} = 0$. As regards timber supply from final fellings, the effect of a higher interest rate remains ambiguous. This is because a higher opportunity cost of capital renders reforestation investments less attractive. However, it is plausible that the positive effect of a higher stock holding cost will dominate, because the growing stock represents a much larger input of capital.

Management costs have only indirect effects on the harvesting decision. A result worth noting is that higher reforestation costs will discourage final fellings ($H_w < 0$ as $F_{KE} < 0$). Finally, the model suggests a one-to-one relationship between the *initial stock* of timber and the first-period harvest. This is because the optimal stock is independent of the initial stock and a bang-bang adjustment is involved (see section 3.3).

Optimal management intensity

The effects of exogenous variables on management intensity are given in (3.13):

$$\text{(3.13)} \quad \begin{aligned} E_{p_1} &= -H_w \lesseqgtr 0 \text{ as } F_{KE} \gtreqless 0 \\ E_{p_2} &= D^{-1}p_2[-F_EF_{KK} + (1+F_K)F_{KE}] \begin{smallmatrix}>0\\=?\end{smallmatrix} \\ &\quad \text{as } F_{KE} \overset{\geq}{<} 0 \\ E_r &= D^{-1}p_2[wF_{KK} + p_1F_{KE}] \begin{smallmatrix}<0\\=?\end{smallmatrix} \text{ as } F_{KE} \overset{\geq}{<} 0 \\ E_w &= D^{-1}(1+r)p_2F_{KK} < 0 \\ E_Q &= 0. \end{aligned}$$

The *current stumpage price* has only an indirect effect (the negative of the effect of management cost on the harvesting decision). With p_1, the current harvest increases and the remaining growing stock decreases. Measures such as fertilization ($F_{KE} > 0$) are reduced, but reforestation measures (with $F_{KE} < 0$) increase; in part just because more hectares are cut. An expected increase in the *future price* has a positive direct effect on investments owing to an increase in their marginal returns. Overall, measures such as fertilization are unambiguously increased (a higher desired stock implies a higher marginal response to inputs of fertilizer), as are measures on currently nonharvestable stands. For regeneration measures, on the other hand, the overall effect remains ambiguous since an expected future price increase encourages the forest owner to hold current stands longer.

A higher *interest rate* implies a higher opportunity cost on capital. Thus, its direct effect on management intensity is negative. This effect is amplified for measures augmenting the growth of current stands by the indirect effect due to a lower optimal stock ($E_r < 0$ where $F_{KE} > 0$). On the other hand, reforestation measures tend to increase indirectly because a higher interest rate serves to speed up the realization of the standing timber.

Summary of comparative statics

It is useful to summarize the main effects of various exogenous factors in an unambiguous manner. An inspection of (3.12) and (3.13) reveals that there is no ambiguity whenever $F_{KE} \geq 0$, since both effects work in the same direction. In the case $F_{KE} < 0$, it seems reasonable to assume that where both direct and indirect effects arise, the *direct* effects dominate. Under this simplification, the results can be stated as indicated by the signs below each exogenous variable:

$$\text{(3.14a)} \quad H^* = H^*(\underset{+}{p_1}, \underset{-}{p_2}, \underset{+}{r}, \underset{?}{w}, \underset{1}{Q})$$

$$\text{(3.14b)} \quad E^* = E^*(\underset{?}{p_1}, \underset{+}{p_2}, \underset{-}{r}, \underset{-}{w}, \underset{0}{Q}).$$

As this assumption helps to clarify the conclusions and also seems empirically justifiable[7], it will be repeatedly used below.

3.3 Long-run steady state timber supply

As stated earlier, the long-run timber supply refers to the average sustainable harvest level. As opposed to the short-run supply (limited by an arbitrary initial stock of mature stands), the long-run supply is constrained by forest growth over time. Based on an endogenously determined optimal growing stock, the concept refers to an established equilibrium state beyond the adjustment period (Clark 1976, Binkley 1987). Note that this definition is met by the second-period harvest in the three-period model: the second period's initial stock is endogenous, and it also is a non-terminal period. As usual, the long-run timber supply will be considered as a steady state notion. Specifically, consider a *stationary steady state* with all relative prices assumed unchanging over time. With $p_i = p$, $w_i = w$ and r constant, the conditions (3.9a) and (3.9b) become

$$\text{(3.15a)} \quad [1 + F_{K_1}(.)][1 + F_{K_2}(.)] = (1+r)^2$$

$$\text{(3.15b)} \quad [1 + F_{K_2}(.)] = (1+r),$$

which imply

$$\text{(3.16)} \quad 1 + F_{K_1}(.) = 1 + r.$$

Further, (3.15b) and (3.16) imply $F_{K_1}(K_1,E_1) = F_{K_2}(K_2,E_2)$. According to (3.15b) and (3.16), the stationary solution always has $F_K(.) = r > 0$, which means that the optimal stock is always lower than the MSY stock. Similar implications can be derived from the first-order conditions (3.9c) and (3.9d) with respect to the management intensity. Consequently, it can be concluded that

(3.17a) $K_1^* = K_2^*$

(3.17b) $E_1^* = E_2^*$.

In other words, the optimal growing stock is equal for periods 1 and 2. The same applies to the optimal management intensity (in fact, this would hold for all periods $i < N$ with any N). Finally, substituting the expressions for first and second-period post-harvest growing stocks from (3.6), it can be seen that (3.17a) is equivalent to

(3.18) $H_2 = F(Q - H_1, E_1) = F(K_1, E_1)$.

Denoting the long-run supply by h, it can thus be written

(3.19) $h = H_2 = F(K_1^*, E_1^*)$.

According to (3.19), the *long-run steady state timber supply* is equal to *forest growth at the optimal growing stock and management intensity*.[8] For the stationary case, $h_i = F(K^*, E^*) = h$ (constant) for all $i \in (1, N - 1]$. Accordingly, the solutions of the model can be summarized as follows:

(1) The first-period harvesting decision is defined in terms of an optimal growing stock K*, to which the arbitrary initial stock is adjusted. The cutting rule requires that the marginal rate of return on the growing stock equals the opportunity cost of capital. With given and time invariant stumpage prices and costs, the first-period harvest readily leads to the long-run optimum stock.

(2) In the second period as well as every (non-terminal) period beyond the first one, the amount of steady state growth at the optimum stock and management intensity is harvested. Thus, after the initial adjustment period, the growing stock is kept at the constant steady state optimum level.

It should be noted, first, that an interior solution with $H_1^* > 0$ is assumed. In other words, it is assumed that $Q > K^*$ so that the growing stock is adjusted by cutting. A corner solution with $H_1^* = 0$ would follow if $Q < K^*$ so that approaching the optimal stock requires waiting for the stock to grow. The interior solution implies $F_K(.) \leq 0$, resulting in a very large optimal stock, as $p_2 \geq (1 + r)p_1$, while $F_K(.) > 0$ with the stock strictly below the MSY level otherwise. Thus, a zero harvest is more likely when the initial stock is small and a significant increase in real stumpage prices is expected. Since in Finland, at least, neither of these assumptions seems "representative", the corner solution is not considered.

Secondly, the solutions for short and long-run timber supply are discrete time counterparts of the bang-bang control and steady state harvest found in continuous time models for renewable resources. (For the basic model and its solution, see Johansson & Löfgren 1985, Clark 1976). Note that the "bang-bang" control is optimal because the budget constraints are linear with respect to the quantity harvested. This is reasonable for a "small" forest owner facing given stumpage prices. For a large-scale timber producer, the analysis could be modified by taking the stumpage prices to be decreasing in the quantity sold. Then, a gradual rather than bang-bang adjustment might be optimal.

Properties of the long-run supply

As the long-run solution h is similar for all periods $i \in (1, N - 1]$, its qualitative properties can be found by using the second-period solution

(3.19') $h = F(Q - H_1^*, E_1^*)$.

Noting that $h(j) = F[Q - H(j), E(j)]$, the comparative statics for h are obtained by simply substituting the first-period optimal solutions or reaction equations $H^* = H^*(p,r,w,Q)$, $E^* = E^*(p,r,w,Q)$ into the growth function in (3.19'). With respect to any exogenous variable $j = (p,r,w,Q)$, it is obtained by the chain rule

(3.20) $h_j = \partial h / \partial j = -F_K(.)H_j^*(.) + F_E(.)E_j^*(.)$.

Changes in the exogenous variables can influence the long-run supply *directly*, both through the growing stock (harvesting decision) and through the management intensity (investment decision). These effects are shown by the first and second terms in (3.20), respectively. Moreover, there may be *indirect* effects due to interactions between K and E that are represented by F_{KE} involved in H_j or E_j. To evaluate the effects, note that the first-order conditions of the stationary case imply $F_K(.) = r > 0$ and $F_E(.) = (1 + r)wp^{-1} > 0$. Inserting $p_i = p$ into the first-order conditions and re-solving, the comparative statics results in (3.12) and (3.13) simplify to $H_p = -D^{-1}pF_EF_{KE} \lesseqgtr 0$ as $F_{KE} \gtreqless 0$ and $E_p = -D^{-1}pF_EF_{KK} > 0$. That is, the optimal management intensity unambiguously rises if there is a stumpage price increase perceived as permanent. Regarding the harvesting decision, a permanent increase in the stumpage price level has only indirect effects. Consequently, the current harvest from fertilized thinning stands decreases as a higher stock level becomes optimal ($F_{KE} > 0$), while reforestation and hence clearcutting ($F_{KE} < 0$) are encouraged.

Substituting the short-run results H_j, E_j and rearranging, the comparative statics for the long-run timber supply can be stated as follows:

(3.21a) $h_p = D^{-1}pF_E(F_KF_{KE} - F_EF_{KK}) \begin{smallmatrix} > 0 \\ = ? \end{smallmatrix}$ as $F_{KE} \begin{smallmatrix} \geq \\ < \end{smallmatrix} 0$

(3.21b) $h_r = D^{-1}p[rpF_{EE} + (1 + r)w^2p^{-1}F_{KK} - wF_{KE}]$
$\begin{smallmatrix} < 0 \\ = ? \end{smallmatrix}$ as $F_{KE} \begin{smallmatrix} \geq \\ < \end{smallmatrix} 0$

(3.21c) $h_w = D^{-1}(1 + r)p[-F_KF_{KE} + F_EF_{KK}) \begin{smallmatrix} < 0 \\ = ? \end{smallmatrix}$
as $F_{KE} \begin{smallmatrix} \geq \\ < \end{smallmatrix} 0$

(3.21d) $h_Q = 0$.

A higher stumpage price level tends to increase the sustainable harvest by means of a greater management intensity, but the (indirect) effect through the growing stock depends on the specific case. Where E represents fertilization ($F_{KE} > 0$), the optimal stock increases so that the stock effect is positive. Thus, the overall effect is also positive, as is that for measures like brush control in seedling stands ($F_{KE} = 0$). On the other hand, to the extent that a higher price level encourages reforestation measures ($F_{KE} < 0$), the consequent increase in harvesting tends to reduce the optimal growing stock and hence the sustainable harvest. A higher interest rate implies a higher opportunity cost of capital and tends to reduce the sustainable harvest. This is because it discourages long-range investments, and because higher stock holding costs imply a lower growing stock. Compared to these two direct effects, the indirect one is unlikely to be of much importance. The main effect of higher management costs is the negative impact through a reduction in management intensity. Finally, the long-run supply is independent of the initial stock.

Summary of comparative statics

The results in (3.21a) through (3.21c) indicate that the direct effects are unambiguous in all cases. For p and w, the only direct effect appears through E while for r, direct effects through both K and E work in the same direction. Even the indirect effects work in the same direction with the direct ones whenever $F_{KE} \geq 0$. That is, the results are unambiguous for interpretations of E such as fertilization, drainage, pre-commercial thinning and/or brush control, or the establishment of new stands. Ambiguities arise only where clearcutting and reforestation intensity are considered ($F_{KE} < 0$). Assuming that the direct effects dominate over the indirect ones, the results can be summarized as

(3.22) $h = h(\underset{+}{p}, \underset{-}{r}, \underset{-}{w}, \underset{0}{Q})$.

According to (3.22), the long-run timber supply is increasing in the stumpage price level and decreasing in the interest rate and management costs.

3.4 Conclusion

It was shown above that the two-period model sufficiently represents the forest owner's short-run timber supply in that the first-period decisions are qualitatively independent of the number of periods to come (as suggested without detailed analysis by Max 1983, p. 32). Moreover, the results of the two-period model can also be used to analyze the long-run timber supply. The latter holds given that the budget constraints are linear in the choice variables so that a bang-bang adjustment is optimal. Interestingly, the solutions are parallel with the solution concepts of the well-examined continuous time optimal control models for renewable resources. The discrete time current harvest and long-run supply prove to be the counterparts of the bang-bang adjustment and steady state harvest, respectively. On the other hand, the results may be compared with the optimal rotation model. A comparison can be found in Appendix 1. The comparative statics results, especially the results for the long-run supply in (3.21) and (3.22), are qualitatively very similar to those indirectly obtainable from the rotation model. In the two-period model, however, the results are analytically more accessible.

Some clarifying notes on the nature of the two-period model may be in order. First, the formulation formally suggests that all timber is cut in the second period. While seemingly restrictive, this was seen to be harmless, since the first-period cutting rule is unaffected by the number of periods. Intuitively, the model represents adaptive decision-making with the standing stock repeatedly allocated between the present harvest and the future; then, a terminal period in which all timber is literally cut need never really happen. (Note that the time periods in the model are not equal to calendar years. The present period might be taken to be 5 years, for example. In particular, the second period does not refer to next year but represents all future periods lumped together).

Secondly, the density dependent "lumped-parameter" growth function ignores the fact that forest growth not only depends on the volume of the biomass per hectare but also on its age distribution. For a general discussion on the suitability of age vs. size dependent growth functions, one may refer to Reed & Clarke (1990). While most important for practical management planning, the age issue is considered unimportant here, since the aim is qualitatively characterizing the harvesting decision rather than providing quantitative solutions. The mean age of the trees could in fact be incorporated into the growth function as a coefficient $g = g(t) > 0$, with $g'(t) < 0$ to highlight the fact that the growth rate of trees declines with age (Clark 1976, p. 264), to obtain $F^t = g(t)F(Q - H,E)$. The mean age of the remaining trees, in turn, depends on the current harvest, $t = t(H)$. As the sign of $t'(H)$ depends on the specific cutting practice, the formulation would produce ambiguous results without economic insight.

Finally, compared to the Faustmann rule, it may seem "erroneous" that the cutting rule makes no adjustment for the land rent considerations. In fact, a counterpart of the land rent factor could be explicitly incorporated.[9] However, the standard growth function can be used for simplicity without loss of qualitative insight.

Notes to Chapter 3

[1]An example of specific functional forms with the assumed curvature is the logistic growth function frequently used in bioeconomics (e.g. Clark 1976, Braun 1978, Wilen 1985), which implies the standard S-shaped yield curve characteristic of various density-dependent populations. The basic form is

$$F(K) = \rho_0 K[1 - K/C],$$

where ρ_0 is the intrinsic growth rate (maximum per capita growth rate, $\lim_{K \to 0} F(K)/K$) and C is the carrying capacity of the site. Management intensity can enter in two ways (see Tahvonen 1989 for pollution impacts). First, the carrying capacity may be affected, i.e. $C = C(E)$ with $C' > 0$, $C'' < 0$ (e.g. fertilization or drainage). It can be shown by differentiation that the assumptions in (A.1) hold, with $F_{KE} > 0$, for all $K \in (0,C)$, $E > 0$. Secondly, the intrinsic growth rate may change, or $\rho_0 = \rho_0(E)$ with $\rho_0' > 0$, $\rho_0'' < 0$ (e.g. increased reforestation intensity, faster-growing species, etc.). Also in this case, all other assumptions in (A.1) hold for all $K \in (0,C)$, $E > 0$ (with $F_{KE} \gtreqless 0$ as $K \lesseqgtr C/2$, while $F_{KK}F_{EE} - (F_{KE})^2 > 0$ at least for all $K \in (0.22C, 0.78C)$ with E arbitrarily close to zero and over a wider range given $E > 0$. An estimable approximation could be the quadratic function

$$F(K,E) = \alpha_1 K + \alpha_2 E + \alpha_{11} K^2 + \alpha_{22} E^2 + \alpha_{12} KE$$

with $\alpha_1, \alpha_2 > 0$ and $\alpha_{11}, \alpha_{22} < 0$ (graphically, a downward opening parabola). The age of trees and the site index could be added (see Nautiyal & Couto 1984).

[2]Diminishing marginal returns for the growing stock (basal area) and the nutrient input are supported by Nautiyal & Couto (1984), which also shows a positive interaction between the two. With respect to the initial planting density and site index, comparable to fertilization, see the yield functions in Chang (1983, 1984).

[3]The cross partial of the production function has a similar role in the neoclassical theory of input demand. Following Ferguson (1969), K and E are complements if $F_{KE} > 0$ and competitive if $F_{KE} < 0$. The complementary relation usually prevails, and if there is a range of competitiveness, then a range of complementarity must also exist. If $F_{KE} = 0$, the function is separable in K and E. (This terminology should not be confused with Hicks-Allen complements vs. substitutes; e.g. Ferguson, p. 71).

[4]The intrinsic growth rate increases with the carrying capacity of the site unchanged. Stands established with greater site preparation and advanced-age seedlings for shorter regeneration lags, higher planting density, or faster-growing improved material converge to the maximum volume more rapidly (Chang 1984).

[5]First, denote the area clearcut and replanted by $A = A(H)$, with $A' > 0$, $A'' = 0$ (for simplicity, the latter ignores the marginal impact that successive increments in H might call for younger stands with lower stocking to be cut). Thus, timber growth due to subsequent stands is $g = g(A(H),E)$ with $g_A > 0$, so $g_H = g_A A'(H) > 0$. Assuming $g_{AA} = 0$ (all hectares of equal productivity), $g_{HH} = g_{AA}A'(H)^2 + g_A A''(H) = 0$. Secondly, the cross partial derivative g_{HE} must be positive. The partial g_H measures the increase in second-growth timber production due to a change in H via more hectares cut and replanted, and g_{HE} is the change in g_H due to E. Naturally, the contribution of each hectare replanted, thus g_H, will rise with the reforestation intensity so that $g_{HE} > 0$.

[6]For a graphical illustration of the separation of consumption and harvesting decisions, see Fig. 2.1 in Kuuluvainen (1989). In this particular case, the optimal production decisions as such could be solved from a present value maximization problem. Still, there are particular reasons to use the utility maximizing approach. For example, the expenditure – or consumption – tax (section 5.3 and Appendix 4) or unpriced nontimber values (Chapter 6) could not be considered in a present value model.

[7]Regarding the current harvest, the qualitative results for the current and expected stumpage prices, as well as the interest rate, are supported by empirical studies on NIPF owners' short-run timber supply (e.g. Kuuluvainen *et al.* 1988, Hetemäki & Kuuluvainen 1991, Brännlund *et al.* 1985, Newman 1987, Hultkrantz & Aronsson 1989; Kuuluvainen 1989, Kuuluvainen & Salo 1991, Aronsson 1990a). For the initial stock, instead, the result $H_Q = 1$ does not seem to be consistent with findings based on micro data on NIPF owners' harvesting behavior in Finland and Sweden. According to Kuuluvainen (1989) or Kuuluvainen and Salo (1991), the elasticity of timber sales per hectare with respect to the per-hectare timber stock was well below one (0.40). Aronsson (1990a) found both even lower (0.16) and somewhat higher (0.58) elasticity estimates. Several explanations may exist. First, the empirical measurement of the harvesting potential is not without problems. Secondly, the assumed immediate downward adjustment of the stock may be hampered in practice. Thirdly, the stock itself may impute utility (see Chapter 6).

[8]Graphically, K* and E* are determined by the point of tangency between the well-behaved growth function F(K,E) and a plane surface in (K,E,F) space, which satisfies the slope conditions defined in the first-order conditions. With F(.) strictly concave in both K and E, the uniqueness of the solution is clear. (Assuming that F_E eventually becomes negative, F(.) will have the 'egg-half' shape shown in Vehkamäki (1986, Fig. 1) or Omwami (1988, Fig. 3a)).

[9]Where final fellings and reforestation are considered, the growth specification $F(Q - H,E) = f(Q - H) + g(H,E)$ could be used. As a consequence, $F_K(.)$ in condition (3.11a) would be replaced by $[f'(K) - g_H(.)]$. That is, the marginal cost of the current harvest is not equal to the forgone marginal growth of the old-growth stock alone but lower than that, or f'(.) *minus* the marginal return from the subsequent stands, $g_H(.) > 0$. The term $-g_H(.)$ thus recognizes the subsequent stands and encourages old-growth stands to be cut earlier, as does the land rent term in the Faustmann rule (Samuelson 1976, Hyde 1980). On the other hand, the interaction term F_{KE} would in this case be replaced by $-g_{HE} < 0$ (end note 5). (Under long rotations, the land rent issue has to do with marginal changes in the timing of receipts accruing several human generations ahead; with t around 70 to 100 years and common interest rates, e.g. 3–4 %, the term $[1 - e^{-rt}]^{-1}$ is close to unity).

4 The effects of forest taxes: a positive analysis

Chapter 4 contains a positive analysis of the impacts of forest taxation. "Positive" here refers to the study of how each of the taxes is likely to affect the representative forest owner's forest management decisions, considering changes in one tax variable at a time. In contrast, Chapter 5 takes a normative view and considers which one of the forest tax bases is desirable with respect to a stated criterion (economic efficiency). In section 4.1, the tax regimes to be considered are first defined in more detail and the background for treating each of them is briefly discussed. The effects of various taxes on the harvesting decision (short-run timber supply) and management intensity are established in section 4.2, and in section 4.3, the results are used to derive the effects on the long-run timber supply. Throughout Chapters 4 and 5, only consumption – i.e., the income from timber production – is assumed to matter to both the forest owner and the policy-maker.

4.1 Definitions of forest tax systems

In the present study, lump-sum (or site productivity), realized income or yield, and *ad valorem* property taxes will be considered.[1] First, the label *lump-sum* tax is used to refer to taxes paid annually per hectare of forest land according to site quality, regardless of the actual harvest or timber stocking. The basic case is the *unmodified site productivity tax*. For example, the productivity taxation in Finland, dating back to the 1920's, was virtually an unmodified site productivity tax until 1980. Also, site value taxes are of the lump-sum type (as is the property tax on forests in Finland). While the estimated taxable income is a lump sum, the actual amount of tax to be paid annually may depend on the forest owner's personal tax rate and, thus, total income.

Secondly, *realized income taxes* – in the forestry context usually known as yield taxes (also, harvest or sales taxes) – are levied on the stumpage value of timber only at the time of harvest. Only proportional yield taxes are examined in this study, i.e., the tax rate is a fixed per cent of the actual harvest value. Two variations of realized income taxation are considered to distinguish between taxes levied on the net vs. gross value of timber. The *profit tax* (e.g. Englin & Klan 1990) is based on the stumpage income net of management costs. That is, actual costs are fully deductible (thus, the profit tax is equivalent to the realized income tax with immediate deductibility of costs as presented by Kovenock 1986). Under the *gross yield tax*, no allowance for costs is made, or only a fixed per cent of harvest value is deducted on an average basis. A special motivation for considering these taxes is that according to current proposals (Pääomatulojen … 1991, Puun myyntitulojen … 1992), a proportional realized income tax at the uniform capital income tax rate is to be introduced in Finland.

Thirdly, the *ad valorem property tax* is defined as a tax levied annually at a given per cent of the market value of the standing stock. As only the potential harvest value of the timber is taxable, it is a "timber tax", as distinct from the unmodified property tax levied on the value of the timber and forest land. *Ad valorem* property taxes are commonly applied, and have been much discussed, in the U.S. (e.g. Klemperer 1976, 1977, 1982, 1983, Chang 1982, 1983, Stier & Chang 1983, Kovenock & Rothschild 1983, Kovenock 1986, Boyd 1986, Gamponia & Mendelsohn 1987). Another reason for treating the property tax here is the proposed weighting of the site productivity tax in Finland by the woodlot's age distribution. According to the suggestions (Riihinen 1982, Puuhuollon … 1985), the per-hectare tax would increase with the age class of the stand. However, discrete age classes are mathematically inconvenient. A proportional tax on the value of standing timber is therefore used to represent such an age dependent tax regime (a tax burden increasing with stand age being basically equivalent to one increasing with the stocking level).

In addition to the three main taxation types, Chapter 5 will briefly consider the *accrual income tax*, whereby the taxable income is defined as the realized income plus any change in the value of the standing stock. While realized income taxes are frequently used for administrational reasons (the accrual income tax would require a re-evaluation of the property's timber stock at times), realized income is in fact not a satisfactory concept of income. In the case of appreciating assets such as timber, its conceptual inappropriateness seems particularly clear and tends to result in inefficiency. The accrued income, instead, would duly recognize the nature of forestry income. It would also meet the Haig-Simons comprehensive definition of income (e.g. Musgrave 1985) as including not only the relevant period's consumption (realized income) but also any capital gain or loss. However, accrual income taxation need not be considered in detail, because the *ad valorem* property tax, based on the value of the standing stock, is equivalent to taking the changes in the stock into account as taxable income.

4.2 Effects on short-run timber supply and management intensity

As shown in Chapter 3, the effects of taxes on the short-run timber supply, management intensity, as well as the long-run supply, can be analyzed using a two-period model. Thus, assume the forest owner behaves as if he/she maximized the discounted utility of consumption over two periods ('today' and 'the future'),

(4.1) $U = u(c_1) + \beta u(c_2),$

subject to the relevant budget constraints. The notation is similar to Chapter 3, with the modification that i = (1,2). To economize on the number of formulas, the lump-sum and profit taxes are written into the budget constraints simultaneously (section 4.2.1). The gross yield and *ad valorem* property taxes are considered in separate sections.

4.2.1 Lump-sum and profit taxes

The lump-sum tax, to be denoted by Λ_i (i = 1,2), is a reduction in the disposable income independent of the values of any decision variables. The profit tax, denoted by π_i, implies a proportional reduction in the timber sales revenue net of management costs. Thus, the first and second-period budget constraints with the lump-sum and profit taxes included become

(4.2a) $c_1 = (1-\pi_1)(p_1H_1 - wE_1) - S - \Lambda_1$

(4.2b) $c_2 = (1-\pi_2)p_2H_2 + (1+r)S - \Lambda_2.$

Solving and substituting S from (4.2a) into (4.2b), the intertemporal budget constraint is obtained. Substituting this into (4.1) along with $H_2 = Q - H_1 + F(Q - H_1, E_1)$ and omitting the time subscripts of H_1 and E_1, the problem can be written as

(4.3) $\underset{\{c_1,H,E\}}{\text{Maximize}}\ U = u(c_1) + \beta u(c_2)$

where $c_2 = (1-\pi_2)p_2[Q - H + F(Q-H,E)] + (1+r)[(1-\pi_1)(p_1H - wE) - \Lambda_1 - c_1] - \Lambda_2.$

The first-order conditions for an interior solution are

(4.4a) $U_{c_1} = u'(c_1) - \beta u'(c_2)(1+r) = 0$

(4.4b) $U_H = \beta u'(c_2)\{-(1-\pi_2)p_2[1+F_K] + (1-\pi_1)p_1(1+r)\} = 0$

(4.4c) $U_E = \beta u'(c_2)\{(1-\pi_2)p_2F_E - (1-\pi_1)w(1+r)\} = 0.$

Given β, u'(.) > 0, the separation result of Chapter 3 continues to hold. Thus, the second-order conditions will always hold under the properties of F(.) stated in (A.1). The harvesting and management intensity decisions are determined by the two conditions:

(4.5a) $-(1-\pi_2)p_2[1 + F_K(Q-H,E)] + (1-\pi_1)p_1(1+r) = 0$

(4.5b) $(1-\pi_2)p_2F_E(Q-H,E) - (1-\pi_1)w(1+r) = 0.$

As the *lump-sum taxes* Λ_1, Λ_2 do not appear in the optimality conditions (4.4) or (4.5), it is readily seen that the lump-sum tax is neutral with respect to the harvesting and management intensity decisions. The conclusion holds whether temporary or permanent changes are considered, i.e., whether the level of taxation is constant or varies over time. This is because lump-sum payments leave the marginal revenues and costs unchanged. Note that the lump-sum tax is equivalent to the site value or site productivity taxes (Chang 1983, Gamponia & Mendelsohn 1987), or the taxation of "pure income" from forestry (Vehkamäki 1986).

In (4.5), the *profit tax* is equivalent to a proportional reduction in the stumpage price *and* unit cost of silvicultural inputs. Note that the definition differs from the yield tax in Chang (1983) or Gamponia & Mendelsohn (1987), as well as from the *ad valorem* sales tax in Vehkamäki (1986), where management costs are not deductible. With $\pi_1 \neq \pi_2$, changes in the tax rates will affect the after-tax relative prices $(1-\pi_2)p_2/(1-\pi_1)w$ and $(1-\pi_2)p_2/(1-\pi_1)p_1$ and thereby the optimal decisions. But if $\pi_1 = \pi_2$, both current and future stumpage prices and the factor cost change by the same proportion and relative prices remain unchanged. Formally, the effects are as follows:

(4.6a) $H_{\pi_1} = D^{-1}(1-\pi_2)(1+r)p_2\{p_1F_{EE} - wF_{KE}\} \begin{smallmatrix}<0\\=?\end{smallmatrix}$ as $F_{KE} \begin{smallmatrix}\geq\\<\end{smallmatrix} 0$

$H_{\pi_2} = -(1-\pi_2)^{-1}p_2 H_{p_2} \begin{smallmatrix}>0\\=?\end{smallmatrix}$ as $F_{KE} \begin{smallmatrix}\geq\\<\end{smallmatrix} 0$

$H_{\pi} = 0$

(4.6b) $E_{\pi_1} = D^{-1}(1-\pi_2)(1+r)p_2\{-wF_{KK} + p_1F_{KE}\} \begin{smallmatrix}>0\\=?\end{smallmatrix}$ as $F_{KE} \begin{smallmatrix}\geq\\<\end{smallmatrix} 0$

$E_{\pi_2} = -(1-\pi_2)^{-1}p_2 E_{p_2} \begin{smallmatrix}<0\\=?\end{smallmatrix}$ as $F_{KE} \begin{smallmatrix}\geq\\<\end{smallmatrix} 0$

$E_{\pi} = 0.$

If $\pi_1 = \pi_2 = \pi$, the marginal cost and marginal revenue with respect to harvesting and management intensity change equiproportionally, so their ratio remains unaltered. Thus, the profit tax is neutral if the tax rate is expected to remain constant over time (or any changes are perceived as permanent). This agrees with the results from the rotation model (Kovenock 1986, section V; Johansson & Löfgren 1985, p. 96). An important precondition for the result is the full deductibility of management costs. However, temporal variations in the profit tax rate matter. The distinction between direct and indirect effects (section 3.2) applies. Whenever $F_{KE} \geq 0$, the results are unambiguous, since the indirect effects work in the same direction as the direct ones. Assuming the direct effects dominate where $F_{KE} < 0$, the results can be summarized as

(4.7) $H = H(\underset{-}{\pi_1}, \underset{+}{\pi_2}, \underset{0}{\pi}),\quad E = E(\underset{+}{\pi_1}, \underset{-}{\pi_2}, \underset{0}{\pi})$

for all types of silvicultural measures. According to this, a rise in the current profit tax rate will reduce the current harvest by reducing its marginal revenue, if perceived to be temporary. Under the same proviso, management intensity tends to increase due to a decline in the after-tax management cost relative to the marginal return (future stumpage price). On the other hand, an expected rise in the future tax rate means that the future after-tax price declines. This will encourage the forest owner to cut more in the current period but discourages forestry investments.

4.2.2 *Gross yield tax*

Assume next that the tax base is the gross stumpage value at harvest time, with no allowance for silviculture. Alternatively, the tax could be levied on the harvest revenue deducted by an arbitrary proportion to allow for the average management costs, best taken as the reforestation cost. The reason for considering this case is that verifying the silvicultural measures taken and estimating their true costs on an individual basis might require too much administrational work. Denoting the gross yield tax by γ_i and the rate of tax deduction by proportion d of the harvest value, the budget constraints become

$$\text{(4.8a)} \quad c_1 = (1-\gamma_1^*)p_1H_1 - S - wE$$
$$\text{(4.8b)} \quad c_2 = (1-\gamma_2^*)p_2H_2 + (1+r)S,$$

where $(1-\gamma_i^*) = [1-\gamma_i(1-d)]$. The marginal conditions for the harvesting and management intensity decisions will be

$$\text{(4.9a)} \quad -(1-\gamma_2^*)p_2[1+F_K(Q-H,E)] + (1-\gamma_1^*)p_1(1+r) = 0$$

$$\text{(4.9b)} \quad (1-\gamma_2^*)p_2F_E(Q-H,E) - w(1+r) = 0.$$

Compared to the profit tax, (4.9b) involves w instead of $(1-\pi_1)$w. In other words, the yield tax in effect reduces the stumpage price while leaving the unit cost of silviculture unaffected. Therefore the gross yield tax with $\gamma_1 = \gamma_2$ is equivalent to the yield or *ad valorem* sales tax in Chang (1983), Gamponia & Mendelsohn (1987) or Vehkamäki (1986). As the management costs are not fully deductible, the gross yield tax differs from the profit tax in that even a constant yield tax rate changes the ratio of marginal revenue and cost with respect to silvicultural measures. The same qualitative results will hold whether $d = 0$ or $0 < d < 1$. Formally, the results are

$$H_{\gamma_1} = D^{-1}(1-d)(1-\gamma_1^*)p_1p_2(1+r)F_{EE} < 0$$
$$\text{(4.10a)} \quad H_{\gamma_2} = D^{-1}(1-d)(1-\gamma_2^*)p_2^2[F_EF_{KE} - (1+F_K)F_{EE}] \underset{=}{\overset{>}{?}} 0 \text{ as } F_{KE} \gtrless 0$$
$$H_{\gamma} = D^{-1}(1-d)p_2^2F_EF_{KE} \gtreqless 0 \text{ as } F_{KE} \gtreqless 0$$

$$E_{\gamma_1} = D^{-1}(1-d)(1-\gamma_2^*)p_1p_2(1+r)F_{KE} \gtreqless 0 \text{ as } F_{KE} \gtreqless 0$$
$$\text{(4.10b)} \quad E_{\gamma_2} = D^{-1}(1-d)(1-\gamma_2^*)p_2^2[F_EF_{KK} - (1+F_K)F_{KE}] \underset{=}{\overset{<}{?}} 0 \text{ as } F_{KE} \gtrless 0$$
$$E_{\gamma} = D^{-1}(1-d)p_2^2F_EF_{KK} < 0.$$

Assuming the direct effects dominate, the results can be summarized as

$$\text{(4.11)} \quad H = H(\underset{-}{\gamma_1}, \underset{+}{\gamma_2}, \underset{?}{\gamma}),\ E = E(\underset{?}{\gamma_1}, \underset{-}{\gamma_2}, \underset{-}{\gamma}).$$

Compared to the profit tax, the major conclusion is that the gross yield tax is no longer neutral, even if the tax rate remains constant over time. While the direct effect on the harvesting decision vanishes, there is an indirect effect. Taking the case $F_{KE} < 0$ to represent clearcutting and reforestation decisions (Chapter 3), the result $H_\gamma < 0$ for $F_{KE} < 0$ means that even a constant yield tax γ will reduce short-run timber supply. This is because the tax discourages reforestation investments and thereby final fellings of mature stands. Similarly, the gross yield tax unambiguously discourages silvicultural measures ($E_\gamma < 0$ irrespective of F_{KE}). As (4.9b) indicates, this is because γ, in effect, reduces the marginal return on investments but leaves their marginal cost unaffected.

4.2.3 *Ad valorem property tax*

The *ad valorem* property tax is considered as a proportional tax on the value of the standing stock. More specifically, each period's tax base is the value of timber stock remaining after the harvest in the beginning of the period. As the stock equations of the two-period model imply that, formally, all timber is cut in the second period, the second-period tax would become zero. While harmless in fact, this suggests *a priori* that the results may be biased, as the current period is followed by one with no tax at all. Therefore, a three-period setting is used to analyze the property tax. Denoting the *ad valorem* property tax by α_i, the taxes for periods 1 through 3 are[2]

$$\alpha_1p_1K_1 = \alpha_1p_1(Q-H_1)$$
$$\text{(4.12)} \quad \alpha_2p_2K_2 = \alpha_2p_2[Q-H_1+F(Q-H_1,E_1)-H_2]$$
$$\alpha_3p_3K_3 = 0.$$

Inserting the tax terms in (4.12) into the budget constraints and simplifying, the problem becomes formally similar to (3.7). Therefore, the formulation and complete first-order conditions are not repeated. The conditions for optimal H_i and E_i (i = 1,2) will be:

$$\text{(4.13a)} \quad -p_3(1+F_{K_1})(1+F_{K_2}) + (1+r)^2p_1(1+\alpha_1) + (1+r)\alpha_2p_2(1+F_{K_1}) = 0$$

$$\text{(4.13b)} \quad -p_3(1+F_{K_2}) + (1+r)p_2(1+\alpha_2) = 0$$

$$\text{(4.13c)} \quad p_3(1+F_{K_2})F_{E_1} - (1+r)^2w_1 - (1+r)\alpha_2p_2F_{E_1} = 0$$

$$\text{(4.13d)} \quad p_3F_{E_2} - (1+r)w_2 = 0.$$

Eq. (4.13b) implies $p_3(1+F_{K_2}) = (1+r)p_2(1+\alpha_2)$. Substituting this into (4.13a) and (4.13c), the rules for the optimal first-period harvest and management intensity become

$$\text{(4.14a)} \quad \frac{p_2}{p_1(1+\alpha_1)}[1+F_{K_1}(.)] = 1+r$$

$$\text{(4.14b)} \quad \frac{p_2}{w_1}F_{E_1}(.) = 1+r.$$

For the harvesting decision, (4.14a) suggests that the *ad valorem* property tax is effectively like a multiplicative *increase in the current stumpage price* by the tax rate α_1. Alternatively, (4.14a) can be written in the form

$$\text{(4.14a')} \quad \frac{p_2}{p_1}[1+F_{K_1}(.)] = (1+r)(1+\alpha_1).$$

The latter form indicates that, as regards the harvesting decision, the property tax is equivalent to an *additive increase in the interest rate.* This compares with the earlier findings based on the optimum rotation model (Chang 1983, Kovenock 1986, Gamponia & Mendelsohn 1987), as well as the analysis by Vehkamäki (1986) based on size dependent growth. The rate of increase in the effective opportunity cost of capital is approximately equal to the tax rate α_1, because $(1+r)(1+\alpha_1) = 1 + r + \alpha_1 + r\alpha_1 \approx 1 + (r+\alpha_1)$. Considering management intensity, (4.14b) suggests that the property tax has no direct impact on the optimal decision, as the tax rate does not appear in the rule. Formally, the comparative statics are obtained from the simultaneous equations

$$\text{(4.15a)} \quad -p_2[1+F_K(Q-H,E)] + (1+\alpha_1)p_1(1+r) = 0$$
$$\text{(4.15b)} \quad p_2F_E(Q-H,E) - w(1+r) = 0,$$

and the results are as follows:

$$\text{(4.16a)} \quad H_{\alpha_1} = H_\alpha = -D^{-1}p_1p_2(1+r)F_{EE} > 0$$

$$\text{(4.16b)} \quad E_{\alpha_1} = E_\alpha = -D^{-1}p_1p_2(1+r)F_{KE} \lesseqgtr 0 \text{ as } F_{KE} \gtreqless 0$$

$$\text{(4.16c)} \quad H_{\alpha_2} = E_{\alpha_2} = 0.$$

Notably, only the current property tax rate α_1 matters for current decisions. As the results for α_1 and α are the same, it makes no difference whether the tax rate is expected to vary over time or remain constant. The fact that α_2 does not matter means that expectations of future changes in the tax rate are irrelevant. In other words, changes in the property tax rate are taken into account, in a myopic manner, as they occur.[3]

First, the *ad valorem* property tax unambiguously increases the short-run timber supply. (4.16a) indicates that there is only a direct effect. Comparison with (3.12) shows that the overall effect on short-run supply is formally equivalent to that of the current stumpage price. Secondly, (4.16b) suggests that the property tax has no direct effects on the management intensity decision. This may seem surprising, as it might be expected that a tax on the future stock would discourage investments that aim at augmenting the stock. Indeed, Chang (1983) found that the *ad valorem* property tax reduces both the optimal planting density and rotation length.

The apparent contradiction stems from a difference in the setup. In the present model, the property tax is imposed on the growing stock remaining after each period's harvest. In contrast, capital investments in forestry are not taxed as they occur, but their contributions will only become taxable when realized in an increased growing stock. In every period, a new harvesting decision is made whereby the growing stock can be adjusted to its "appropriate" level, given the then current tax rate. Consequently, there is no need to anticipate future tax rates by choosing e.g. a lower planting density so as to escape taxes in the distant future. Thus, there is only an indirect effect that depends on the sign of the interaction term. By (4.16b), measures such as fertilization are thereby discouraged ($E_\alpha < 0$ as $F_{KE} > 0$), since a lower growing stock implies a decline in their marginal product. Precommercial thinnings, etc. ($F_{KE} = 0$) remain unaffected, while regeneration measures are indirectly increased with an increase in final fellings.

Summary of the results

To conclude, the *ceteris paribus* effects on short-run supply and management intensity of the various forest taxes can be summarized as

$$
(4.17)\quad
\begin{array}{l}
H = H(\underset{0}{\Lambda};\ \underset{-}{\pi_1},\ \underset{+}{\pi_2},\ \underset{0}{\pi};\ \underset{-}{\gamma_1},\ \underset{+}{\gamma_2},\ \underset{?}{\gamma};\ \underset{+}{\alpha_1/\alpha},\ \underset{0}{\alpha_2}) \\[2ex]
E = E(\underset{0}{\Lambda};\ \underset{+}{\pi_1},\ \underset{-}{\pi_2},\ \underset{0}{\pi};\ \underset{?}{\gamma_1},\ \underset{-}{\gamma_2},\ \underset{-}{\gamma};\ \underset{?}{\alpha_1/\alpha},\ \underset{0}{\alpha_2}).
\end{array}
$$

The neutrality of the lump-sum tax holds irrespective of whether the tax rate is expected to vary over time. The gross yield tax, unlike the profit tax, is never neutral (recall that direct effects are assumed to dominate). Finally, the effects of the *ad valorem* property tax are the same for the current or constant tax rate (temporary or permanent changes). In fact, correct results for the latter case would have been obtained by using the two-period model, because expectations of the future tax rate proved to have no role.

4.3 Effects on long-run timber supply

Turning next to the permanent, long-run effects of forest taxes, the long-run steady state timber supply was defined in section 3.3 as

$$(4.18)\quad h(n) = F[Q - H^*(n), E^*(n)].$$

Consequently, the effect of any tax (n) on the long-run timber supply can be analyzed by substituting its impacts on the short-run supply and management intensity decisions into

$$(4.19)\quad h_n = \partial h/\partial n = -F_K(.)H^*_n + F_E(.)E^*_n(.).$$

Assuming a stationary steady state implies that the tax rates are taken to be constant over time. Also, it is known that $F_K, F_E > 0$. Assuming that (for γ and α) the direct effects dominate, the results can be first summarized as follows:

$$(4.20)\quad h = h(\underset{0}{\Lambda},\ \underset{0}{\pi},\ \underset{-}{\gamma},\ \underset{-}{\alpha}).$$

The *lump-sum* and *profit taxes* are neutral with respect to the long-run supply. According to the short-run results, the lump-sum tax is neutral regardless of variations in the tax rate. By (4.6a) and (4.6b), neutrality applies to the profit tax when perceived to be constant over time. For the *gross yield tax*, (4.10a) and (4.10b) imply

$$(4.21)\quad h_\gamma = D^{-1}(1 - d)p^2F_E[F_EF_{KK} - F_KF_{KE}] \begin{smallmatrix}<0\\=?\end{smallmatrix}$$

$$\text{as}\quad F_{KE} \underset{<}{\geq} 0.$$

By (4.21), the gross yield tax tends to reduce the long-run timber supply. First, there is an unambiguously negative direct effect from a reduction in the management intensity. Secondly, there is an ambiguous indirect effect through the optimal growing stock. Assuming the direct effect dominates, the result is $h_\gamma < 0$. This coincides with Chang's (1983) result that the yield tax tends to lengthen the rotation and lower the planting density, which in turn tends to reduce the long-run supply (see Appendix 1). According to Vehkamäki (1986), an *ad valorem* sales tax reduces both forestry investments and the equilibrium growing stock and harvest. The present study has shown that the stock effect, depending on F_{KE}, can in fact take any sign. However, the main conclusions coincide.

Finally, for the *ad valorem property tax*, substituting (4.16a) and (4.16b) implies

$$(4.22)\quad h_\alpha = D^{-1}p^2(1 + r)[F_KF_{EE} - F_EF_{KE}] \begin{smallmatrix}<0\\=?\end{smallmatrix} \text{ as } F_{KE} \underset{<}{\geq} 0.$$

This suggests that the property tax also tends to reduce long-run supply, but through a different mechanism. First, it has an unambiguously negative direct effect through a reduction in the optimal growing stock. Secondly, there is an indirect effect, associated with the management intensity decision, which is uncertain in sign. If the direct effect dominates, the result is $h_\alpha < 0$. According to Chang (1983), the property tax may reduce both the planting density and the rotation age. Where this is the case, it will unambiguously reduce the long-run timber supply as suggested here (in some cases, the results remain uncertain).[4]

Notes to Chapter 4

[1]For the forest tax terminology, recommended references are Klemperer (1976, 1983) and Chang (1982, 1983), as well as Max & Lehman (1988), Englin & Klan (1990), and Kovenock (1986).

[2]Note that the standing stock in each period is simply assumed to be valued at the same period's stumpage price. In other words, the analysis ignores complications that might arise from delays in the re-valuation procedure.

[3]This depends on the fact that the representative forest owner model, due to exogenous stumpage prices, is linear in the current harvest. Accordingly, an immediate or 'bang-bang' adjustment of the growing stock is both possible and optimal (Clark 1976, Johansson & Löfgren 1985). For the forest owners as a whole, for example, this is not the case because a very large supply in a given period would lead to a price reduction.

[4]In Vehkamäki (1986), the effect of a "timber tax" on the equilibrium stock depends on the direction of stumpage price change. This is because the price in his model follows a continuous time path. In the present setup, similar implications would arise if the expected future price were assumed to change with observed changes in the current price, i.e. $p_2 = f(p_1)$.

5 The relative efficiency of forest taxes: a normative analysis

This chapter turns to the normative analysis of forest taxation, i.e., the choice of a desirable forest tax regime with respect to a stated criterion. Specifically, forest taxes are analyzed from the *relative efficiency* point of view. While the basic purpose of taxation is raising revenue for public expenditure, production efficiency requires that taxes levied for this purpose should be designed so as to distort economic decisions as little as possible.[1] More formally, the *excess burden* of taxation at any given level of tax revenue should be kept to a minimum.

Section 5.1 first discusses the concept of excess burden in general and shows how this conceptual starting point can be specifically applied in the present context. Section 5.2 considers the efficiency of the common forest taxes in an initially undistorted economy by analyzing the effects of compensated switches between forest taxes. Section 5.3 introduces capital income taxation as an important example of nonforest taxes that matter for forest management decisions. The appropriate forest tax regime, given the initial tax distortion, is then solved using the criterion of intra and intersectoral efficiency of investment. Section 5.4 makes some concluding remarks.

5.1 Excess burden and the efficiency of taxes

5.1.1 Conceptual remarks

The excess burden of a tax (also known as deadweight loss, efficiency loss, or welfare cost) is the amount that is lost in excess of what the government collects (Auerbach 1985, p. 67), or the loss of welfare above and beyond the tax revenues collected (Rosen 1985, p. 276). The measure can be defined by using demand and supply curves and the concepts of consumers' and producers' surplus (see Appendix 2, Fig. A2.1). (As the timber market is in question, the terms sellers' and buyers' surplus will be used below). Consider a proportional sales tax on any commodity or a yield tax on timber (Chapter 4). As this is effectively like a reduction in the price received by the seller, a tax wedge is generated between the seller's price and the price paid by timber users. With a reduction in the seller's effective price, the quantity sold is reduced. An excess burden consequently arises because the reduction in the seller's surplus is greater than the tax revenue collected. However, the concept must be defined more generally. Three important remarks are briefly made below (the reader is referred to Appendix 2 for a more detailed argument).

First, while a tax-induced reduction in output may be the most typical instance of excess burden, it is not the only one. Excess burden *does not only follow from a reduction in output* and income thereby lost, but from any distortion of an efficient allocation (e.g. Auerbach 1985, p. 68). Remarkably, even a subsidy (a negative tax) generates a positive excess burden. (Note that the excess burden is always nonnegative; e.g. Ng 1979, Auerbach 1985, p. 67).

Secondly, a crucial fact is whether or not *pre-existing tax distortions* are present prior to the tax considered. Where no distortions initially exist, it is obvious that for forestry, for example, a neutral tax should be chosen to preserve the initial allocation. However, the initial allocation may be inefficient due to pre-existing taxes (or instances of market failure). Then, the efficiency effects of forest and other relevant taxes must be considered as a whole (cf. Rosen 1985, p. 286). Rather than choosing a neutral tax, the forest tax regime could be designed to offset the pre-existing distortion; neutrality is an appropriate objective only when defined with respect to the entire tax system (Kovenock 1986).

Thirdly, *only substitution effects are relevant* when defining the excess burden. Such effects are due to tax-induced changes in the marginal revenues and costs, i.e. relative prices. In contrast, income effects related to the reduction in disposable income are not a symptom of economic inefficiency (The Structure … 1978). The excess burden can be defined as the reduction of utility in excess of that which would occur if the given amount of tax were collected as a lump sum (e.g. Rosen 1985, p. 278). On the other hand, lump-sum taxes have income effects only, so the result means that the excess burden is represented by the loss of utility above and beyond the income effect.

5.1.2 Applying the measure

Rather than numerically measuring the excess burden in specific cases, this study aims at general conclusions on the relative efficiency of forest taxes. For such a qualitative analysis, operational counterparts for the concept of excess burden are needed. Throughout Chapter 5, only the income from timber production is assumed to matter. Section 5.2 additionally assumes that no tax distortions pre-exist. In this case, it turns out that minimizing the loss of production efficiency is equivalent to analyzing the effects of compensated switches between forest taxes on the long-run timber supply. The reasoning behind this solution principle is three-fold.

First, according to Gamponia & Mendelsohn's (1987) definition of the excess burden, the efficiency of forest taxation requires minimizing the present value of lost income from tax-induced distortions at any given level of tax revenue. Where only the commercial timber matters, the excess burden will be minimized if the forest tax base is chosen so as to maximize the present value of stumpage income (which is just the mirror image of minimizing losses therein). Further, this simply implies *maximizing the long-run steady state timber supply, subject to a given tax revenue requirement*, as a proxy (see section 5.2).

Secondly, Koskela (1989a,b) analyzed the effects of compensated switches between forest taxes, which keep the total tax revenue unchanged. The same procedure will be used to maximize the *long-run* timber supply subject to a tax revenue target. (The effects of compensated tax switches on the short-run supply are also considered to represent the *transitional* effects of an anticipated or announced switch, but have no normative status).

Thirdly, public forest policies have traditionally been concerned with the adequacy of sustainable timber supplies. Seeking to keep the long-run timber supply as large as possible thus seems intuitively reasonable. To anticipate the outcomes, neutral forest taxes appear desirable under these assumptions. As a neutral tax imposes no reduction in output, its excess burden is zero; by the nonnegativity of excess burden this must be the limiting case.

While valid in a special case, this solution is limited: it only holds under the assumption of no pre-existing distortions, and suggests that a tax-induced reduction in the stumpage income is the sole source of excess burden. However, some distortions may indirectly *subsidize* forestry, and direct tax subsidies are often involved in forest taxation. While increasing timber production, they may imply a misallocation of resources.

Section 5.3.1 therefore introduces a more general approach based on the notion of *intra and intersectoral efficiency of investment* (Kovenock & Rothschild 1983, Kovenock 1986). Given no forest taxes or other initial distortions, the forest owner's optimal management decisions (Chapter 3) imply that the marginal rate of return on the growing stock and other inputs equals the interest rate. Assuming the capital market is efficient, the interest rate represents the general pre-tax rate of return on investment, i.e., the social opportunity cost of capital. Then, the private marginal conditions also represent efficient (socially optimal) investment decisions. The correct forest tax rule calls for choosing nondistortive (neutral) forest taxes so as to retain an efficient allocation.

In section 5.3.2, a capital income tax on the interest from financial assets (deductibility of interest charges) is introduced. This is equivalent to a reduction in the effective interest rate, which no longer reflects the true social opportunity cost of capital. While seemingly favorable to forestry in the long run, a reduction in the interest rate discourages timber harvesting. As timber is held too long, too much capital is tied into the mature timber compared to other assets.

As the private solution prior to forest taxes does not coincide with a social optimum, neutral forest taxes are no longer consistent with efficiency. Instead, production efficiency in forestry requires that forest taxation should *offset the management distortions from capital income taxation*. Thus, the correct tax rule now calls for a "corrective" forest tax structure to *restore* the efficiency of investment. Following Kovenock & Rothschild (1983) and Kovenock (1986; also, Englin & Klan 1990), the undistorted, untaxed solution is compared in section 5.3.3 to the private solution which includes both the capital income tax and each type of forest tax in turn.

It is useful to relate the present approach with the recent literature on the theory of optimal taxation (for reviews, see Auerbach 1985, Slemrod 1990). The typical problem in optimal taxation is to determine a structure of taxes which minimizes the excess burden – i.e., the loss of individual utility (optimal commodity taxation) or production efficiency (production taxes on firms or suppliers of inputs) – at any given level of tax revenue. In more sophisticated models, distributional considerations may be involved. In the present case, this would amount to a general equilibrium analysis to simultaneously determine the optimal structure of both capital income and forestry taxes, which minimizes their overall excess burden across all relevant sectors in the economy. While an interesting topic for future research, this is beyond the scope of this study. The main features of the present approach and/or its differences from a typical optimal tax analysis can be summarized as follows.

First, efficiency will only be met in the sense that the distortionary effects of capital income taxation on forest management decisions are corrected (i.e., the excess burden of the two taxes *in the forestry sector* becomes zero). This is not the case as a whole, since the distortions in intertemporal consumption-savings decisions remain. Thus, imposing a corrective tax on forestry alone represents a partial equilibrium solution. (Also, it could be characterized as second-best policy (e.g. Ng 1979), involving piecemeal improvements in a single sector at a time where a first-best solution is hampered for some reason. Note, however, that optimal taxation in general is a second-best problem, since lump-sum taxes are usually ruled out). Secondly, the tax revenue is not fixed to a given level. For policy purposes, the implied level of tax burden must therefore be considered separately. In fact, the "corrective" forest tax rates are logically similar to what is known as 'pigouvian tax formulas' after Pigou (1920; for pigouvian forest taxes, see Englin & Klan 1990). Also, note that the study focuses on production efficiency, while the effects on the tax-payers' (forest owners') welfare are not considered.

In summary, capital income taxation is taken to be a given, uncorrectable distortion. The structure of forest taxation is then designed to neutralize its effects on forest management decisions. Accordingly, the resulting forest tax regime is "optimal" in the sense of production efficiency in the forestry sector alone. As regards implications to forest tax policy, such a partial solution is in fact the realistic choice, because capital income taxation is bound to be maintained for both political and fiscal reasons.

5.2 Efficient forest taxation in an initially undistorted economy

5.2.1 Long-run effects of compensated tax switches

This section turns to the choice of a desirable (economically efficient) forest tax base under the assumption that no management distortions prior to forest taxes exist. Another important assumption (to be relaxed in Chapter 6) is that only timber production matters. Thus, the excess burden is simply the present value of income lost for tax-induced distortions (Gamponia & Mendelsohn 1987). Minimizing income losses, in turn, is equivalent to maximizing the present value of the sustainable harvest at any given level of tax revenue. Note that a representative forest owner is considered and that given stumpage prices are accordingly assumed. (As will be shown in Chapter 8, taking into account the price adjustments due to tax-induced shifts in aggregate timber supply would reduce the effects of forest taxes, without changing the qualitative conclusions concerning their relative efficiency).

Denote timber price by p, the sustainable harvest by h, the interest rate by r, and the vector of relevant tax parameters by **b**. Then, efficiency is formally met by choosing the forest tax structure **b** so as to

$$(5.1)\quad \max_{\{\mathbf{b}\}} PV = ph(\mathbf{b})/r \quad \text{s.t. } T(\mathbf{b}) = T^0,$$

where T^0 is a given tax revenue requirement. With p and r constant, the quantity $ph(\mathbf{b})/r$ clearly is maximized at the same point as h. Accordingly, a valid rule for the choice of a forest tax base in this case is simply *maximizing the long-run steady state timber supply* subject to a tax revenue requirement.

In the present study, the primary problem is the choice among a number of discrete tax base alternatives rather than setting the value of a continuous tax rate (the latter aspect also enters in the following section). Thus, the problem is conveniently solved by analyzing the effects of compensated switches between two types of tax at a time, with their total tax revenue held at the target level (Koskela 1989a,b). Specifically, switches from the lump-sum tax towards other taxes will be considered. This is because choosing a neutral tax as the point of reference simplifies the analysis. (Naturally, lump-sum taxation in the form of site productivity or site value taxes is also of practical relevance). Denote the long-run timber supply as a function of the lump-sum tax Λ and an alternative forest tax n by

(5.2) $h = h(\Lambda, n)$.

Suppose there is a switch from the lump-sum tax towards tax type n so that the increase in taxes collected by n is compensated by an equal reduction in the lump-sum tax. That is, the present value of total tax revenue is kept at the target level (for the profit tax, for example, $\Lambda r^{-1} + \pi(ph - wE)r^{-1} = T^0$). The resulting change in long-run timber supply is expressed by the total differential

(5.3) $dh = h_\Lambda d\Lambda + h_n dn$.

Because $h_\Lambda = 0$ by Chapter 4, (5.3) reduces to $dh = h_n dn$. The effect of a switch from Λ towards n then simplifies to

(5.4) $dh / dn_{(n,\Lambda|T=T^0)} = h_n$.

In other words, when the reference case is the neutral lump-sum tax, the effect of a compensated switch reduces to the *ceteris paribus* effect of the alternative tax.

By (5.4), the effect of a switch from the lump-sum tax towards any of the other taxes is obtained by using the results in Chapter 4. For a switch to the *profit tax*,

(5.5) $dh / d\pi_{(\pi,\Lambda|T=T^0)} = 0$,

since $h_\pi = 0$ according to (4.20). That is, the choice between the lump-sum and profit taxes does not matter in terms of long-run timber supply. Note, however, that for the realized income tax to be neutral, management costs must be fully deductible and the tax rate must be constant over time. For the *gross yield* or *ad valorem property tax*, (4.21) and (4.22) imply

(5.6) $dh / dn_{(n,\Lambda|T=T^0)} = h_n \underset{=\,?}{<0}$ as $F_{KE} \underset{<}{\geq} 0$

for $n = \gamma, \alpha$.

A switch towards either the gross yield tax or the *ad valorem* property tax tends to reduce the long-run timber supply compared to lump-sum taxation. The effect is unambiguously negative whenever $F_{KE} \geq 0$, and the same also holds for $F_{KE} < 0$ if the direct effects dominate.

The policy implications of the results are as follows. First, where timber production only matters and no tax distortions pre-exist, neutral forest taxation is desirable since it provides the highest long-run timber supply at any given tax revenue. Specifically, the choice between lump-sum taxes (the unmodified site productivity tax or site value tax) or the profit tax does not matter from the efficiency point of view. Secondly, any of the neutral taxes outperform the gross yield tax or the *ad valorem* property tax, which both tend to reduce the long-run supply of timber. The relative performance of the latter two remains *a priori* ambiguous (see Appendix 3).

An additional note concerning yield taxes may be useful. A well-known result from the basic rotation model suggests that the (gross) yield tax, by lengthening rotations, will increase the long-run timber supply (cf. Appendix 1). Thus, the goal of maximizing long-run supply would seem to favor yield taxation. However, this conclusion is no longer valid when the management intensity is incorporated and/or alternative applications of yield taxation are recognized. The gross yield tax will reduce the long-run supply via an unambiguously negative impact on the management intensity, while via the growing stock (cf. rotation age, Chang 1983), there is only an ambiguous indirect effect. On the other hand, the profit tax – with full deductibility of costs – is neutral when constant over time, and thereby equivalent to lump-sum taxation in terms of long-run timber supply.

5.2.2 *Transitional effects*

Even if the normative analysis is mainly concerned with the long-run effects of alternative forest tax bases, the *transitional effects* must also be taken into account if a switch to a completely new tax regime is considered. In practice, such a major reform cannot be put into effect overnight, and a transition period is usually required. Therefore, the effects on short-run timber supply and management intensity of an *anticipated or announced switch* are examined (while unanticipated tax base switches are not considered relevant). Formally, the future tax base is assumed to change to see how expectations of a tax switch affect the current timber supply and management intensity decisions during the transition period.

Suppose there is a compensated switch in future taxation from the lump-sum tax towards a non-lump sum tax n (with lump-sum and profit taxes, for example, the tax revenue is $\Lambda_1 + (1 + r)^{-1}\Lambda_2 + \pi_1(p_1H_1 - wE) + (1 + r)^{-1}\pi_2p_2H_2 = T^0$). Given that $H = H(\Lambda_2, n_2)$ and $E = E(\Lambda_2, n_2)$, the effects of a switch between Λ_2 and n_2 are indicated by the total differentials $dH = H_{\Lambda_2} d\Lambda_2 + H_{n_2} dn_2$ and $dE = E_{\Lambda_2} d\Lambda_2 + E_{n_2} dn_2$. Since $H_{\Lambda_2} = E_{\Lambda_2} = 0$, the first terms vanish. Again, the effects of compensated changes therefore reduce to the *ceteris paribus* effects, i.e.

(5.7a) $dH / dn_{2\,(n_2,\Lambda_2|T=T^0)} = H_{n_2}$

(5.7b) $dE / dn_{2\,(n_2,\Lambda_2|T=T^0)} = E_{n_2}$.

Consider, first, a switch to profit or gross yield taxation. The results in (4.6) and (4.10) imply

(5.8a) $dH / dn_{2\,(n_2,\Lambda_2|T=T^0)} = H_{n_2} \underset{=\,?}{>0}$ as $F_{KE} \underset{<}{\geq} 0$

(5.8b) $dE / dn_{2\,(n_2,\Lambda_2|T=T^0)} = E_{n_2} \underset{=\,?}{<0}$ as $F_{KE} \underset{<}{\geq} 0$

for $n_2 = \pi_2, \gamma_2$.

By (5.8), an anticipated switch from lump-sum taxation towards either the profit or gross yield tax tends to increase harvesting but decrease the management intensity during the transition period. Secondly, suppose a switch to the *ad valorem* property tax is expected. According to (4.16),

(5.9a) $dH / d\alpha_{2\,(\alpha_2,\Lambda_2|T=T^0)} = H_{\alpha_2} = 0$

(5.9b) $dE / d\alpha_{2\,(\alpha_2,\Lambda_2|T=T^0)} = E_{\alpha_2} = 0$.

Interestingly, (5.9) suggests that expectations of a switch to the *ad valorem* property tax will affect neither timber supply nor management intensity decisions during the transition period, although the property tax was found to be nonneutral. As discussed earlier (Chapter 4), the basic reason is that an immediate adjustment of the standing stock – i.e., selling any amount of timber without affecting the unit stumpage price – is possible for the representative forest owner. Consequently, changes in the *ad valorem* property tax are taken into account as they occur rather than adjusting the behavior in anticipation.

An interesting corollary is that the transitional effects of the gross yield and *ad valorem* property taxes appear to be quite different: a switch to yield taxation is likely to cause a major transitive shock before the actual switch, while the property tax would more steadily encourage harvesting after the transition period. Consider the transition process in three stages. At stage (1), a future tax switch has been announced (see the results in (5.8) and (5.9)). At stage (2), the new tax regime has been put into effect and is applied both in the current and future taxation. As stage (3), consider the new long-run equilibrium that is established over time (section 5.2.1).

An announced switch to *yield/profit taxation* is equivalent to a reduction in the expected future stumpage price by the tax rate. Given that yield tax rates might be in the order of 25 per cent, the desired harvest would markedly increase during the transition period, stage (1). Even if the shock were reduced by a consequent reduction in the market prices for stumpage, the standing stock and thereby timber supply at stage (2) might be reduced significantly.[2] At stage (3), the yield/profit tax implies a lower or unchanged equilibrium harvest ($h_\gamma < 0$, $h_\pi = 0$). The results suggest that a switch to the *ad valorem* property tax, in contrast, would not change timber supply during the transition stage (1). The property tax would first increase harvesting when put into effect, at stage (2). Compared to yield taxes, the short-term shocks would even then be less drastical.[3] On the other hand, the effect of the property tax does not vanish when established, as even a constant property tax was shown to encourage harvesting. The long-run supply finally tends to be reduced when the growing stock settles at a lower equilibrium level.

5.3 Efficient forest taxation with pre-existing tax distortions

The assumption of an economy with no initial tax-induced management distortions is likely to be an unrealistic point of departure. This section therefore introduces capital income taxation as an important example of distortions that may exist prior to, or regardless of, forest taxes. If the income from non-forest assets is taxed and the interest charges for loans are tax deductible, the initial allocation will be distorted via a reduction in the effective private opportunity cost of capital. As discussed in section 5.1.2, maximizing the long-run timber supply is no longer a valid criterion for forest taxation. Rather than forest taxes alone, the efficiency effects of forest and other taxes must be considered as a whole.

Section 5.3.1 develops a more general procedure to deal with this case (together with non-timber objectives or tax subsidies in Chapters 6 and 7). To introduce the alternative approach, the results on efficient forest taxation with no other taxes are first restated. Section 5.3.2 analyzes the effects of a uniform capital income tax (deductibility of interest charges) on consumption-savings and forest management decisions. Section 5.3.3 then solves for the appropriate forest tax regime under an income tax on non-forest assets. It will be shown that production efficiency now calls for nonneutral (capital gains) taxation of forestry to offset the initial distortion. Section 5.3.4 shows that, besides an *ad valorem* property tax, efficiency could be attained by an accrual income tax.

5.3.1 Forest taxes and the efficiency of investment

Recall the marginal conditions for the representative forest owner's optimal harvesting and management intensity decisions, with no taxes, in Eqs. (3.11). Letting $p_1 = p_2 = p$ for clarity (the prices would eventually vanish anyhow), (3.11) simplifies to

$$\text{(5.10a)} \quad 1 + F_K(.) = 1 + r$$

$$\text{(5.10b)} \quad F_E(.) = (1 + r)(w / p).$$

To focus on the tax issue, let us assume that the capital and stumpage markets are "by and large" efficient or, rather, ignore the potential failures therein. According to the neoclassical theory of interest, the equilibrium of the capital market under ideal conditions implies that the market rate of interest is equal to the marginal productivity of capital, the opportunity cost of capital, and the social marginal rate of substitution between present and future consumption. (For a brief statement of the standard view, its potential complications and further references, see e.g. Clark (1976, p. 70–72, 87) or Ch. 6 in Dasgupta & Pearce (1978)). The market rate of interest can then be taken to represent the general pre-tax rate of return on investment, i.e., the social opportunity cost of capital. Similarly, the stumpage prices can be taken to reflect the marginal social benefit of a unit of timber cut.

Under these assumptions, the untaxed, undistorted private decisions also represent a socially optimal intertemporal allocation of resources. Eq. (5.10a) determines the private and social optimal growing stock, at which the marginal return on the growing stock equals its opportunity cost (i.e., the pre-tax interest rate representing the rate of social and private returns on alternative assets). Similarly, (5.10b) equates the private and social marginal return on capital invested in silviculture with the returns on investment in other sectors of the economy. Both intra and intersectoral efficiency will be met, because the marginal rates of return on the growing stock, silviculture, and non-forest assets are the same and equal to the social opportunity cost of capital. No reallocation of resources would improve the performance of the economy.

Obviously, forest taxation should leave the harvesting and investment decisions unaltered, once the initial allocation is efficient. For the *lump-sum* and *profit taxes*, (4.5) with $p_i = p$ becomes

$$\text{(5.11a)} \quad 1 + F_K(.) = \frac{1 - \pi_1}{1 - \pi_2}(1 + r)$$

$$\text{(5.11b)} \quad F_E(.) = \frac{1 - \pi_1}{1 - \pi_2}(1 + r)(w / p).$$

Clearly, lump-sum taxation is efficient in this case, since it always leaves the decisions undistorted. The profit tax, in turn, may cause distortions if the tax rate is expected to vary over time. As the terms with π_i vanish when $\pi_1 = \pi_2$, it will be nondistortionary if the tax rate is constant over time. For the *gross yield tax*, (4.9) implies

$$\text{(5.12a)} \quad 1 + F_K(.) = \frac{1 - \gamma_1^*}{1 - \gamma_2^*}(1 + r)$$

$$\text{(5.12b)} \quad F_E(.) = (1 - \gamma_2^*)^{-1}(1 + r)(w / p).$$

The harvesting decision is directly distorted where $\gamma_1^* \neq \gamma_2^*$ but remains unaltered if γ^* is constant. Unlike the profit tax, the management intensity decision is distorted (the marginal product of silvicultural inputs remains higher than the undistorted optimum implies). Thus, the gross yield tax cannot be efficient, as the management intensity will be lower than socially optimal. Finally, (4.14) implies for the *ad valorem property tax*

$$\text{(5.13a)} \quad 1 + F_K(.) = (1 + \alpha_1)(1 + r)$$

$$\text{(5.13b)} \quad F_E(.) = (1 + r)(w / p).$$

With respect to the harvesting decision, the property tax is equivalent to an increase in the interest rate. The marginal product of growing stock at the optimum will be higher and the stocking level lower than efficiency requires. Thus, the *ad valorem* property tax will not meet efficiency under these circumstances (even if management intensity is not directly distorted). Summarizing, the conclusions are equivalent to those in section 5.2.1.

5.3.2 Capital income taxation

Next, suppose there is an income tax on the interest from bank accounts, bonds and other non-forest assets, and interest charges for bank or government loans are tax deductible. A uniform, proportional capital income tax at rate τ is assumed to be symmetrically applied to both savings and borrowing.[4] Both the interest income from savings ($S > 0$) and interest charges for loans ($S < 0$) are consequently reduced by the same fraction. The second-period budget constraint involves $(1 + r)S - \tau rS$ instead of $(1 + r)S$, i.e.

$$\text{(5.14)} \quad c_2 = p_2H_2 + [1 + r(1 - \tau)]S.$$

Denoting $r(1 - \tau) = r^0$, the private optimality conditions now become

$$\text{(5.15a)} \quad U_{c_1} = u'(c_1) - \beta u'(c_2)(1 + r^0) = 0$$

$$\text{(5.15b)} \quad U_H = \beta u'(c_2)\{-p_2[1 + F_K] + p_1(1 + r^0)\} = 0$$

$$\text{(5.15c)} \quad U_E = \beta u'(c_2)\{p_2F_E - w(1 + r^0)\} = 0.$$

According to (5.15), the representative forest owner's effective interest rate becomes the *after-tax* interest rate $r^0 < r$, and the capital income tax is equivalent to a reduction in the interest rate. Clearly, the tax-induced reduction in the effective private opportunity cost of capital will distort both the consumption-savings and forest management decisions. As alternative assets become less attractive and borrowing is encouraged, timber will be held too long. More specifically, consider the intertemporal consumption decisions now characterized by

$$\text{(5.16)} \quad u'(c_1) / \beta u'(c_2) = 1 + r^0 < 1 + r$$

(cf. Chapter 3). Via a reduction in the cost of borrowing and returns on assets, τ tends to switch consumption towards the present and to discourage savings. As the separation result continues to hold, the consumption decision can be analyzed by using (5.15a) with $c_2 = p_2H_2^* + [1 + r(1 - \tau)](p_1H_1^* - wE^* - c_1)$, i.e. treating the harvesting and management intensity decisions as the "predetermined" optimum values denoted by asterisks. Totally differentiating with respect to c_1 and τ, the effect of τ can be written as

$$\text{(5.17)} \quad \frac{\partial c_1}{\partial \tau} = -r\beta \frac{u''(c_2)[1 + r(1 - \tau)](p_1H_1 - wE - c_1) + u'(c_2)}{u''(c_1) + \beta u''(c_2)[1 + r(1 - \tau)]^2} \begin{matrix} = ? \\ > 0 \end{matrix} \text{ as } \begin{matrix} S > 0 \\ S < 0 \end{matrix}$$

where $S = (p_1H_1^* - wE^* - c_1)$. For a borrower ($S < 0$), τ will unambiguously increase current consumption, since both the substitution effect (due to its lower relative price) and the income effect (due to lower interest charges, hence higher disposable future income) are positive. For a net lender ($S > 0$), the effect is ambiguous. While the substitution effect is positive, the reduction in future interest income has an opposite effect (see Sandmo 1985, p. 209).

The harvesting and management intensity decisions are now characterized by

$$\text{(5.18a)} \quad 1 + F_K(.) = 1 + r^0 < 1 + r$$

$$\text{(5.18b)} \quad F_E = (1 + r^0)(w / p) < (1 + r)(w / p),$$

where the stumpage price has been set constant for comparison with (5.10). The optimal private forest management decisions in (5.18) under capital income taxation no longer coincide with the socially optimal allocation, because the marginal rate of return on the growing stock and other inputs in forestry remains lower than the social opportunity cost of capital, or pre-tax rate of return on other assets. Formally, the effects of τ on harvesting and management intensity decisions and long-run timber supply are

$$\text{(5.19a)}\quad H_\tau = D^{-1} r[pF_{EE} - wF_{KE}] \underset{=\,?}{\overset{<\,0}{}} \text{ as } F_{KE} \gtreqless 0$$

$$\text{(5.19b)}\quad E_\tau = D^{-1} r[-wF_{KK} + pF_{KE}] \underset{=\,?}{\overset{>\,0}{}} \text{ as } F_{KE} \gtreqless 0$$

$$\text{(5.19c)}\quad h_\tau = -D^{-1} r\{F_K[pF_{EE} - wF_{KE}] + F_E[wF_{KK} - pF_{KE}]\} \underset{=\,?}{\overset{>\,0}{}} \text{ as } F_{KE} \gtreqless 0.$$

The capital income tax tends to reduce timber harvesting. This follows mainly from the negative direct effect via the opportunity cost of the growing stock (the indeterminate case is due to the positive indirect effect of an implicit subsidy on reforestation investment). As an implicit subsidy to the capital cost, τ on the other hand tends to increase management intensity. Due to positive direct effects through both the growing stock and management intensity, the long-run timber production and potential supply tends to increase. Note, however, that both intertemporal efficiency within forestry and intersectoral efficiency between forestry and other sectors are violated. With no or neutral taxation in forestry, an inefficiency is generated as too much capital is tied to the mature timber relative to other assets. Further, too low-yielding investments in timber growing are encouraged.

5.3.3 Correcting initial tax distortions through forest taxation

The above analysis showed that capital income taxation, even when proportional and symmetric, will distort intertemporal decisions (for more detailed discussion, see e.g. Sandmo 1985). A nondistortionary tax treatment of savings would call for a system whereby the income saved (rather than consumed) is exempted and the interest income is not taxed until withdrawn for consumption. Such an *expenditure tax* (see The Structure … 1978, Boadway & Wildasin 1984, Musgrave 1985) is briefly discussed in Appendix 4. However, there is no experience of applying the expenditure taxation (while some argue it cannot be applied in practice, it has also been suggested that it is exactly for administrational reasons that it *should* be used; see The Structure … 1978). Capital income taxes, with respective interest charge deductions, are most likely to be maintained for both fiscal, political and international reasons. In what follows, a proportional income tax is therefore assumed.

As the initial allocation with capital income taxation is inefficient, neutral forest taxes may no longer be desirable. Instead, efficiency gains could be achieved by designing the forest tax regime so as to reduce the initial management distortions. Next, an appropriate forest tax base and "corrective" tax rate will be determined by searching for a *forest tax regime that exactly offsets the distortionary effect of capital income taxation on forest management decisions*. Note the partial, second-best nature of this solution (section 5.1.2).

Technically, the private optimality conditions (5.11) through (5.13), with the capital income tax inserted, are first re-solved for the marginal products of the growing stock and other inputs. Next, the marginal products are equated with the respective expressions in Eq. (5.10), which represent an undistorted allocation. Then, a tax rate can be found that restores the equality of the marginal rate of return on both inputs at the private optimum with their social opportunity cost or pre-tax rate of return in other sectors (cf. Kovenock & Rothschild 1983, Kovenock 1986, Gamponia & Mendelsohn 1987, Englin & Klan 1990). The corrective tax rate will be a function of the interest rate, capital income tax rate, and other relative prices.

For administrational reasons, using a combination of two forest tax types is not considered relevant. Further, for the suggested tax rate (n^*) to be meaningful, it must be less than one hundred per cent but not zero or negative in order to raise a positive revenue (i.e., $0 < n^* < 1$). Moreover, it will be checked whether a solution with $n_1 = n_2$ is valid. To be relevant for tax policy, the appropriate tax rate should be stable over time.

The lump-sum and profit taxes

With the capital income tax included, the counterpart of (5.11) becomes

$$\text{(5.20a)}\quad 1 + F_K(.) = \frac{1 - \pi_1}{1 - \pi_2}(1 + r^0)$$

$$\text{(5.20b)}\quad F_E(.) = \frac{1 - \pi_1}{1 - \pi_2}(1 + r^0)(w\,/\,p).$$

It is readily seen the that lump-sum tax cannot be efficient, since Λ vanishes in the marginal conditions; a neutral tax cannot possibly correct for the distortion. For the profit tax, equating the R.H.S's of (5.20) with the R.H.S's of (5.10) implies

$$\text{(5.21a)}\quad \frac{1 - \pi_1}{1 - \pi_2}[1 + r(1 - \tau)] = 1 + r$$

$$\text{(5.21b)}\quad \frac{1 - \pi_1}{1 - \pi_2}[1 + r(1 - \tau)](w\,/\,p) = (1 + r)(w\,/\,p)$$

given $r^0 = r(1 - \tau)$. The simultaneous equations in (5.21) must be solved for π_1 and π_2 to see whether an appropriate profit tax rate exists. As the ratio of factor cost to stumpage price w/p vanishes, the two equations in fact collapse to one. According to (5.21a), no constant profit tax rate will do: setting $\pi_1 = \pi_2$ implies $1 + r(1 - \tau) = 1 + r$, which is untrue for any $\tau > 0$. On the other hand, treating π_1 as fixed and solving for π_2 gives

$$\text{(5.22)}\quad \pi_2 = \pi_1 + r\tau(1 - \tau)/(1 + r) > \pi_1.$$

That is, the profit tax could only cancel the effect of τ if the future tax rate is determined (expected) to exceed the current tax rate by a given amount. Clearly, such a result is meaningless from a policy point of view, since the tax rate cannot be steadily increased year by year. Thus, the profit tax cannot be used as a corrective tax. The conclusion is equivalent to that by Kovenock (1986), who shows that a realized income tax, while neutral with respect to the harvesting decision, implies inefficiency when combined with an income tax on the ordinary sector.

The gross yield tax

For the gross yield tax, it is similarly obtained

$$\text{(5.23a)}\quad \frac{1 - \gamma_1^*}{1 - \gamma_2^*}[1 + r(1 - \tau)] = 1 + r$$

$$\text{(5.23b)}\quad (1 - \gamma_2^*)^{-1}[1 + r(1 - \tau)] = 1 + r$$

(the relative price w/p vanishes). To find the optimal γ_1^* and γ_2^*, first solve (5.23b) for $1 - \gamma_2^* = [1 + r(1 - \tau)]/(1 + r)$, which implies $\gamma_2^* = r\tau/(1 + r)$. Substituting $(1 - \gamma_2^*)$ into (5.23a) gives $\gamma_1^* = 0$.[5] The solution

$$\text{(5.24)}\quad \gamma_1^* = 0,\ \gamma_2^* = r\tau/(1 + r)$$

seems strange from a policy point of view: with no tax at all levied in the current period, the forest owners are told that one will be imposed in the future. The future tax rate also seems low regarding the tax revenue. The suggested regime could only be interpreted as a one-time, transitional policy, where all current tax revenue and most of future revenue is actually collected by lump-sum taxes. As a permanent tax regime this is obviously irrelevant, and the gross yield tax fails to be efficient.

The ad valorem property tax

A similar procedure for the *ad valorem* property tax gives

$$\text{(5.24a)}\quad (1 + \alpha_1)[1 + r(1 - \tau)] = 1 + r$$

$$\text{(5.24b)}\quad [1 + r(1 - \tau)] = 1 + r.$$

As the tax rate α_1 is only included in (5.24a), only the harvesting decision can be directly influenced. Since (5.24b), for management intensity, clearly cannot hold for any $\tau \neq 0$, a simultaneous solution for both conditions cannot be found. However, intuition suggests that the the major allocative issue is the accumulation of capital in the mature timber inventory (overaging and, eventually, depreciation of the stock may follow). If this is the case, it is reasonable to accept a tax rate that satisfies (5.24a) alone, i.e., cancels the direct effect of τ on the harvesting decision. The solution becomes

$$\text{(5.25)}\quad \alpha_1 = \frac{r\tau}{1 + r(1 - \tau)}.$$

As it makes no difference whether the *ad valorem* property tax rate varies over time, the optimal α will be constant over time to the extent that r and τ remain constant. Formula (5.25) can be further simplified by noting that $(1 + \alpha)(1 + r^0) = 1 + r^0 + \alpha + \alpha r^0 \approx 1 + r^0 + \alpha$. Using the form $1 + r(1 - \tau) + \alpha \approx 1 + r$ gives the approximation

$$\text{(5.26)}\quad \alpha \approx r\tau.$$

A number of conclusions can be made. First, among the common forest taxes considered above, the *ad valorem* property tax is the only one that can potentially be used as a corrective tax. By properly setting the tax rate, the direct distortion on the harvesting decisions from the capital income tax can be offset. The remaining management intensity distortion seems less of a problem, given that the growing stock represents the dominant stock of capital in timber growing (note that indirect effects are ignored). Secondly, (5.26) suggests that the appropriate property tax rate α is approximately equal to the *pre-tax interest rate* (r) *multiplied by the capital income tax rate* (τ). The solution $\alpha = r\tau$ is equivalent to Kovenock's (1986, p. 205) result. According to Kovenock, both inter and intrasectoral efficiency is attained if a property tax is levied in the Austrian sector at a rate equal to the social discount rate, or pre-tax rate of return in the ordinary sector, multiplied by the income tax rate in the ordinary sector (in Kovenock's notation, $\tau = R\,\tau_0$). Thirdly, as the tax rate is determined by two directly observable factors – and constant over time to the extent that its determinants are – the solution appears feasible for policy purposes.

However, practically setting the appropriate property tax rate is not without difficulty (administrational problems are omitted at this point; see Chapter 8). The relevant interest rates in fact vary across individuals. (Also, the effective capital income tax rate τ differs between borrowers and lenders if the tax on interest income and interest charge deductions are determined asymmetrically. See end note 4). Further, formula (5.26) is derived for analytic purposes from a model where all variables are expressed in real terms. For numerical estimates of α, the role of inflation must be explicitly considered, in order to distinguish between nominal and real interest rates, because both capital income taxes and interest charge deductions are actually based on *nominal* magnitudes. Appendix 5 shows how to take this into account and provides numerical examples.

5.3.4 A note on the accrual income tax

It was shown above that realized income taxation in forestry, even if neutral as such, results in inefficiency when combined with an income tax on other assets. The delay in the realization time of timber is due to the fact that realized income taxation fails to recognize the capital gains aspect of changes in the forest property's value. Therefore, even if the capital income tax is levied at a uniform rate on forestry and other sectors, an asymmetry prevails: investment in the standing timber are tax exempted while other assets are taxed. The *ad valorem* property tax, in contrast, can attain efficiency, since – given a frequent enough re-valuation of the property – unrealized increments in the growing stock, as well as reductions therein, will be recognized.

Another way to achieve the same result is to define the taxable income from forestry on an *accrual* rather than realization basis. Under the accrual income taxation, the tax base is defined as the realized net income *plus* any change in the potential harvest value of the standing stock compared to the previous period. Unlike the profit or gross yield taxes, the unrealized capital gain is added to the realized income while a reduction in the standing stock is deducted (the harvest in excess of the forest's increment represents a transfer of wealth between the forest and other assets rather than real income). Denoting the accrual income tax rate by κ_i and the previous period's growing stock and stumpage price by K_0 and p_0, the budget constraints are

$$(5.27a)\quad c_1 = (1-\kappa_1)(p_1H_1 - wE) - S - \kappa_1(p_1K_1 - p_0K_0)$$

$$(5.27b)\quad c_2 = (1-\kappa_2)p_2H_2 + (1+r)S - \kappa_2(p_2K_2 - p_1K_1).$$

Noting that $K_1 = Q - H_1$, $H_2 = Q - H_1 + F(Q - H_1, E)$ and $K_2 = 0$ and simplifying, these can be rewritten as

$$(5.27a')\quad c_1 = p_1H_1 - (1-\kappa_1)wE - S - \kappa_1(p_1Q - p_0K_0)$$

$$(5.27b')\quad c_2 = p_2H_2 + (1+r)S - \kappa_2[(p_2 - p_1)(Q - H_1) + p_2F(Q - H_1, E)].$$

The latter form indicates that the accrual income tax is, in effect, a capital gains tax on the forest's *value increment* due to the volume increment and stumpage price change. The optimal harvest and management intensity will be determined by the conditions

$$(5.28a)\quad -(1-\kappa_2)p_2[1 + F_K(.)] + p_1[(1+r) - \kappa_2] = 0$$

$$(5.28b)\quad (1-\kappa_2)p_2F_E(.) - (1+r)(1-\kappa_1)w = 0.$$

Rewriting (5.28) as

$$(5.28a')\quad \frac{(1-\kappa_2)p_2}{p_1}[1 + F_K(.)] = 1 + r - \kappa_2$$

$$(5.28b')\quad \frac{(1-\kappa_2)p_2}{(1-\kappa_1)w}F_E(.) = 1 + r$$

shows, first, that κ_1 does not appear in the cutting rule (5.28a'). That is, the current tax on the realized income and the respective reduction in the capital gains tax exactly offset each other. Secondly, κ_2 appears both as a reduction in p_2 on the L.H.S. of (5.28a') and as a reduction in the interest rate on the R.H.S. As the former effect tends to increase and the latter to reduce the current harvest, the total effect is not readily clear. However, the effect is likely to be small, as the R.H.S. $1 + r - \kappa_2 \approx 1 + r - \kappa_2 - r\kappa_2 = (1+r)(1-\kappa_2)$, so that the terms with κ_2 tend to cancel out. Thirdly, a constant accrual income tax rate κ ($\kappa_1 = \kappa_2$) would resemble κ_2. Considering (5.28b'), κ_1 tends to increase management intensity similarly to a reduction in the factor cost w, while κ_2 tends to reduce it similarly to a reduction in p_2. At a constant rate κ, the accrual tax has no direct effect on the management intensity.

To solve for an appropriate accrual income tax rate to offset the capital income tax τ, insert τ into the private solution and use the above procedure (with $p_1 = p_2$) to get

$$(5.29a)\quad \frac{1 + r(1-\tau) - \kappa_2}{1-\kappa_2} = 1 + r$$

$$(5.29b)\quad \frac{1-\kappa_1}{1-\kappa_2}[1 + r(1-\tau)] = 1 + r.$$

κ_1 does not appear in (5.29a), and the latter condition cannot hold given $\tau > 0$. Following the solution for the *ad valorem* property tax, (5.29a) alone is therefore used to find if some constant τ exists that attains efficiency with respect to the growing stock. Setting $\kappa_2 = \kappa$, this implies

$$(5.30)\quad \kappa = \tau.$$

In other words, an accrual income tax at a rate equal to the capital income tax rate would offset the (direct) distortion on the realization time of timber. The result agrees with that of Kovenock (1986).

5.4 Conclusion

Chapter 5 has considered the choice of a desirable forest tax base from the perspective of economic efficiency, assuming that only the consumption of marketed goods – hence timber production – matters to the representative forest owner as well as the policy-maker (nontimber services of the forest will be allowed for in Chapter 6). The main conclusions are as follows.

First, where no significant tax distortions preexist, neutral forest taxation is desirable. This was shown in two alternative ways. Among the common taxes considered here (excluding any direct or indirect tax subsidies), neutral forest taxes provide the highest long-run timber supply at any given tax revenue. On the other hand, neutral taxes do not distort relative prices and the intra and intersectoral allocation of investment. Specifically, lump-sum taxes, such as the site productivity tax, are desirable in an initially undistorted economy (the same holds for the profit tax, with caution). The gross yield and *ad valorem* property taxes change relative prices and cannot be efficient. The results agree with the conclusions in e.g. Gamponia & Mendelsohn (1987). The transitional effects of compensated tax base switches were also considered.

Secondly, management distortions from capital income taxation were assumed to exist initially. The objective of neutral taxation should then be understood as the neutrality of forest and other taxes taken together. Neutral forest taxes are no longer efficient. For the initial misallocation to be cancelled, forest taxation should encourage the realization of timber to the same extent that the tax-induced reduction in the opportunity cost of capital discourages it. In this case, both lump-sum taxation and realized income taxes, such as the profit or gross yield tax, fail to attain efficiency.

Realized income taxes, even if neutral as such, imply inefficiency when combined with an income tax on other assets. The *ad valorem* property tax, in contrast, seems appropriate. More specifically, a properly chosen property tax rate can induce efficient realization decisions for timber and thereby restore the efficiency of allocation between the standing stock and other assets. Alternatively, an *accrual* income tax can be used. The latter conclusions agree with those by Kovenock & Rothschild (1983) and Kovenock (1986) who show that properly set capital gains taxes on forests can be used to attain production efficiency, while *realized* income taxes on assets such as timber are inconsistent with efficiency under an income tax on other assets.

Notes to Chapter 5

[1]In some cases, taxes can be designed to correct for previous misallocations due to externalities, imperfect competition, etc., or to reduce socially undesirable effects (e.g. The Structure … 1978). Examples are taxes on alcohol and tobacco, as well as "environmental taxes" (CO_2 or sulphur taxes on petroleum or other fossile fuels, taxes on nitric and phosphorous fertilizers, or excise taxes on disposable cans). Such taxes seek to limit the use of and damage from such products. In the case of forestry, neither timber harvesting under well-defined property rights nor the standing forest can reasonably be considered as harmful activities/effects that call for such treatment.

[2]Following a reduction in the standing stock, a negative supply effect at stage (2) is unambiguous. The effect of the tax itself would be negative if the forest owners perceive only the current tax when the new regime has only just become operative ($H_{\pi_1} < 0$, $H_{\gamma_1} < 0$). If both current and future taxes are fully recognized, it would be rather neutral ($H_\pi = 0$, $H_\gamma = ?$).

[3]Both yield and property taxes are equivalent to changes in the seller's perceived price by the tax rate (Chapter 4), but property tax rates in per cent are very small figures compared to yield tax rates (for example, if the annual yield is 5% of the value of an asset, a 1.25% property tax can collect the same revenue as a yield tax at 25%). Hence, the introduction of the property tax would correspond to a very small relative change in the effective stumpage price. (The lack of transitional effects at stage (1) depends on the assumption that the forest owner does not anticipate a reduction in the market price at stage (2). The fact that the relative changes in the effective price are small suggests that the transitional effects remain small even if this assumption were not exactly true).

[4]Capital income taxation takes varied forms and it is subject to change in various countries. During the early 1990's in Finland, for example, the income tax on the interest from savings has been levied as a fixed per cent of interest income "at source", while the impact of interest charge deductions depends on the tax-payer's personal marginal tax rate (also, various forms of savings are treated differently). However, a uniform and symmetric proportional capital income tax has been introduced in Sweden and Norway, and will be introduced in 1993 in Finland, too (Pääomatulojen ... 1991).

[5]That no constant yield tax rate works can also be seen by setting $\gamma_1^* = \gamma_2^*$, so that the tax terms vanish in (5.23a) and (5.23b) alone can be solved for $\gamma^* = r\tau/(1 + r)$. This would offset the impact of τ on the management intensity but no value of γ^* can directly affect the growing stock.

6 Taxation and timber supply with nontimber benefits

So far, timber supply and forest taxation have been analyzed under the assumption that all that matters is the consumption of marketed goods, and thereby the income from timber production. In this chapter the nontimber services of the forest, such as scenic beauty and recreation, are incorporated. The primary purpose is to extend the modelling of timber supply decisions. A second purpose is to examine whether the conclusions on the efficiency of forest taxes are sensitive to the assumptions concerning the forest owner's and/or policy-maker's objectives.

Section 6.1 first discusses the modelling approach and the relationship of a forest's perceived amenity to stand/forest characteristics. Section 6.2 analyzes the harvesting decision with nontimber considerations and its comparative statics properties. The effects of alternative forest taxes are analyzed in section 6.3, and section 6.4 examines their relative efficiency. Both an initially undistorted economy and one with preexisting management distortions from capital income taxation are considered. Section 6.5 concludes by summarizing the results on efficient forest tax regimes from all cases covered in Chapters 5 and 6.

6.1 Modelling approach

The nontimber benefits from a forest, such as scenic beauty and recreation, are usually nonmarketed benefits, nonexclusively available to the public without charge. That is, they represent public goods or a special kind of positive consumption externality, and there is no way for the forest owner to receive compensation for providing them. According to the standard theoretical result on externalities (e.g. Ng 1979, Varian 1978), the market in their presence fails to produce a socially optimal allocation. Following this line of thought, it is to be expected that nontimber considerations are not taken into account by the private forest owners. As far as nonindustrial private forest owners (NIPF) are concerned, however, it has been frequently suggested that the forest owners themselves derive utility from the forest's nontimber services and, therefore, take them into account in forest management decisions.[1] Especially where the owner lives on the property or regularly uses it as a part-time residence, this seems plausible. Therefore, the case where the forest owner takes the nontimber considerations into account is also analyzed in order to examine their implications on the harvesting decision.

The amenity values will be explicitly treated as nonmarketed, unpriced benefits and accordingly incorporated directly into the forest owner's utility function. For simplicity, the production of nontimber services is taken to be proportional to the standing volume. Thus, the standing stock itself, with a positive marginal utility, can be included into the utility function to represent such values (Binkley 1981, Kuuluvainen 1985,1986, Max & Lehman 1988).[2] Given that

clearcut regeneration areas are disliked while mature stands with big trees are usually considered attractive, it seems reasonable to assume that the forest's scenic value, increasing with stand age, also depends positively on the standing volume per unit area. However, it is useful to refer to some empirical findings on how the perceived amenity of a forest depends on various stand/forest characteristics.

According to Kellomäki & Savolainen (1984) and Pukkala *et al.* (1988), mature and relatively sparsely stocked stands of tall trees had the greatest scenic value, with tree size and stand age clearly increasing the valuation.[3] For coniferous stands, the scenic value was two-peaked with respect to the development stage of the stand (Kellomäki & Savolainen). While at its lowest on open areas and higher for seedling stands, the scenic beauty index declined again for sapling stands due to a poor range of vision. After that, the scenic value rapidly increases but peaks as soon as the stand reaches maturity. The results for mean and dominant height, mean breast height diameter, standing timber volume, and stand age were very similar to the development stage. Interestingly, the results suggest that scenic value does not substantially rise after a given "sufficient" level of stem volume has been reached; for example, a virgin forest was not valued higher than a commercially managed single-species coniferous stand. Rather than monotonically increasing the amenity of a forest, the marginal effect of the standing volume tends to zero and eventually becomes negative when the within-stand range of vision and attractiveness for recreation start to decline. As a high number of trees per hectare implies a low amenity, while a high amenity value involves big trees rather sparsely located, the total volume cannot become very high. However, it is not until the timber volume common in commercially managed mature stands is reached that the marginal effect of the standing stock tends to zero (Kellomäki & Savolainen 1984).

The amenity of a forest region may depend on aggregate (forest-wide) factors which differ from the within-stand amenity factors. Within reasonable limits, an increase in the mean timber volume per hectare contributes positively the forest amenity, because the proportion of the least valued open areas and young sapling stands thereby declines while the proportion of mature stands increases. However, the between-stand variation and distant scene have been observed to increase the amenity of a forest region so that seedling stands or even open areas may have a positive value (e.g. Pukkala *et al.* 1988).

In this context, it is reasonable to focus on commercially managed forests mainly used for timber production. The above findings then suggest, first, that while the effect of the standing timber volume is non-monotonic, the marginal utility with respect to the standing stock can be assumed positive (but diminishing) over the relevant range of timber volumes. Secondly, stand age (or tree size) clearly matters. A mature stand with tall trees and moderate density is valued higher than a young stand with a high number of trees, even if the total volumes per hectare are equal. Thus, a separate variable reflecting the size of individual trees might be relevant. However, it will be omitted as its introduction would induce ambiguity in the results without major economic insight.[4]

6.2 The harvesting decision with nontimber considerations

A major consequence of incorporating the imputed utility from the standing forest into the model is that the separation of consumption and production decisions no longer holds. Rather than a 'composite commodity' with the first-period harvest, the second-period harvest becomes a true decision variable. The solution will consequently be more complicated compared to the separation case discussed so far. For the clarity and fluency of the presentation, two simplifications will be made.

First, the management intensity decision will be omitted. Appendix 6 shows that management intensity, in fact, would be separable from the consumption decision and that the inclusion of nontimber values would not directly influence its optimal level if silvicultural measures as such do not affect the decision-maker's utility. In this case, the optimal management intensity could be solved independently and substituted into the problem. Obviously, however, this would bring little insight compared to the earlier analysis. On the other hand, intensive regeneration measures, such as site preparation, may directly impute disutility. If the management intensity directly entered the utility function, it would also be determined simultaneously. With up to five choice variables (including the future, as well as current, intensity decision), the analysis would become too involved. Secondly, following e.g. Johansson *et al.* (1989), the decision-maker's utility function is assumed to be additive separable not only intertemporally but also with respect to income and non-income benefits (i.e., the marginal utility from stock-dependent amenities is independent of the consumption level and *vice versa*). Technically (denoting the utility function by V), the cross partial derivatives $V_{cK} = V_{Kc}$ vanish, which simplifies the analysis (cf. Max & Lehman 1988). A zero cross derivative is also a reasonable first approximation, because V_{cK} might take on alternative signs depending on the specific type of benefits under consideration.

The objective function and constraints

Assume the forest owner behaves as if he/she maximized the discounted utility from the consumption of market goods and nontimber services of the standing forest. The forest owner's preference ordering over the consumption of marketed goods and nonmarket amenities is represented by the additive separable utility function

$$(6.1)\quad V = u(c_1) + v(K_1) + \beta\{u(c_2) + v(K_2)\},$$

where c_i denotes the consumption of goods in period i (i = 1,2) and $\beta = (1+\rho)^{-1}$ as before. The subutility functions u(.) and v(.) exhibit positive and diminishing marginal utilities, i.e. $u', v' > 0$ and $u'', v'' < 0$. Further, the standing stock K_i represents the production of nontimber services. Intuitively, the relevant standing stock variable regarding the environmental value of the forest is each period's minimum stock after harvest. Thus, K_i are defined as

$$(6.2a)\quad K_1 = Q - H_1$$
$$(6.2b)\quad K_2 = Q - H_1 + F(Q - H_1) - H_2.$$

For the growth function $F = F(K_1)$ it is assumed, similarly to (A.1), that $F'(.) \gtreqless 0$ as $K_1 \lesseqgtr M$ and $F''(.) < 0$ for all $K_1 \in (0,C)$.

As the standing stock imputes utility, the future period's harvesting decision no longer implies cutting down all the trees (instead, the utility from the marginal unit of timber in consumption equals the marginal amenity loss). Formally, the strict inequality $H_2 < Q - H_1 + F(Q - H_1)$ will hold, so the harvest possibility constraint is not binding and the second-period harvest H_2 is a choice variable. The budget constraints are

$$(6.3a)\quad c_1 = p_1H_1 + I - S$$
$$(6.3b)\quad c_2 = p_2H_2 + (1 + r)S,$$

where p_i, S, and r denote stumpage prices, net savings and the interest rate as before. Furthermore, the current period's exogenous (nonforest) income I has been included for use in the comparative statics analysis.

The solution

Substituting the intertemporal budget constraint $c_2 = p_2H_2 + (1 + r)(p_1H_1 + I - c_1)$, as well as K_1 and K_2 from (6.2), into the objective function, the problem can be written as

$$(6.4)\quad \underset{\{c_1,H_1,H_2\}}{\text{Maximize}}\ V = u(c_1) + v(Q - H_1) + \beta u\{p_2H_2 + (1 + r)(p_1H_1 + I - c_1)\} + \beta v\{Q - H_1 + F(Q - H_1) - H_2\}.$$

The first-order conditions for an interior solution are

$$(6.5a)\quad V_{c_1} = u'(c_1) - \beta u'(c_2)(1 + r) = 0$$

$$(6.5b)\quad V_{H_1} = \beta u'(c_2)(1 + r)p_1 - \beta v'(K_2)[1 + F'(.)] - v'(K_1) = 0$$

$$(6.5c)\quad V_{H_2} = u'(c_2)p_2 - v'(K_2) = 0.$$

Using the subscripts i = (1,2,3) to denote the partials of V(.) with respect to c_1, H_1 and H_2, respectively, the second-order conditions for a maximum can be written as $D_1 = V_{11} < 0$, $D_2 = V_{11}V_{22} - (V_{12})^2 > 0$ and $D_3 = D = V_{11}(V_{22}V_{33} - (V_{23})^2) - V_{12}(V_{21}V_{33} - V_{23}V_{31}) + V_{13}(V_{21}V_{32} - V_{22}V_{31}) < 0$, where D and D_i are the determinants of the Hessian matrix and its principal minor i, respectively. These can be shown to be satisfied for all c_1, H_1 and H_2 under the stated assumptions. Solving (6.5c) for $v'(K_2)$, substituting into (6.5b) and rearranging gives

$$(6.6)\quad \beta u'(c_2)\{-p_2[1 + F'(.)] + (1 + r)p_1\} = v'(K_1).$$

Since $\beta u'(c_2) = u'(c_1)(1 + r)^{-1}$ by (6.5a), this can be rewritten as

$$(6.7)\quad \frac{p_2}{p_1}[1 + F'(.)] = (1 + r) - \frac{v'(K_1)}{p_1\beta u'(c_2)}.$$

To highlight the implications of the nontimber objectives on the harvesting decision, set the marginal utility of standing stock equal to zero. Eq. (6.6) then reduces to

$$(6.6')\quad \beta u'(c_2)\{-p_2[1 + F'(.)] + (1 + r)p_1\} = 0 \iff \{.\} = 0,$$

while (6.7) becomes

$$(6.7')\quad \frac{p_2}{p_1}[1 + F'(.)] = 1 + r.$$

The latter are clearly equivalent to the solution of the basic model in Chapter 3. Two implications are readily seen by comparing (6.6) with the basic case solution (6.6'). First, if the standing stock has value, the harvesting decision is not separable from the consumption decision but depends on the forest owner's consumption plans and preferences, even if the capital market is perfect. Secondly, the positive marginal utility of the standing stock reduces the current harvest. Given β, $u'(c_i)$, $v'(K_1) > 0$, the braced expression {.} in (6.6) must be positive. Accordingly, the marginal revenue of current harvest at the optimum is greater than the marginal cost. In (6.7), the term involving the marginal utility $v'(K_1)$ of the standing stock reduces the R.H.S. compared to (6.7'). Thus, the marginal rate of return on the growing stock will be less than the market rate of interest, which implies that the optimal growing stock remains greater and less will be cut in the current period.

Properties of short-run timber supply

Given the nonseparation of harvesting and consumption decisions, the comparative statics results must be solved from the three simultaneous equations in (6.5). A change in the current price, for example, will affect the current period's harvesting decision through two channels. First, there is the substitution effect due to an increase in the marginal revenue of the current harvest (i.e., the compensated effect of a change in relative prices at a given utility level). Secondly, an increase in the stumpage price also has an income effect, because the income level and attainable consumption at any given harvest thereby increase. The latter effect did not appear in the basic case where the harvesting decisions were independent of the consumption pattern. The total effects are decomposed into compensated and income effects using a technique described by Koskela (1989a). The results are discussed in some detail, because the effects of common forest taxes can be readily understood by comparison with the effects of exogenous income, stumpage prices, or the interest rate. The technical details are presented in Appendix 7.

For notational simplicity, the current harvest H_1 will be denoted below by H. The effect of any exogenous factor j is written in the form $H_j = H_j^c - G_jH_I$. That is, the total effect can be written by using, first, the compensated or substitution effect H_j^c with respect to j. Secondly, the effect of exogenous income H_I is needed to determine the income effect represented by the second term (G_j represents the compensation required to keep the maximum attainable utility unchanged). The comparative statics results are given in (6.8) (for the signs of the compensated and income effects, as well as G_j, see Appendix 7).

$$(6.8a)\quad H_I = -D^{-1}\beta^2u''(c_1)u''(c_2)v''(K_2)(1 + r)[-p_2(1 + F') + (1 + r)p_1] < 0$$

$$(6.8b)\quad H_{p_1} = H_{p_1}^c + HH_I \gtreqless 0$$

$$(6.8c)\quad H_{p_2} = H_{p_2}^c + H_2(1 + r)^{-1}H_I < 0$$

$$(6.8d)\quad H_r = H_r^c + S(1 + r)^{-1}H_I \overset{=\,?}{\underset{>\,0}{}} \text{ as } S \gtrless 0$$

$$(6.8e)\quad H_Q = H_Q^c + p_1H_I \gtreqless 0.$$

According to (6.8a), an increase in the *exogenous income* reduces the current harvest. At a higher income level, there is less of an incentive to increase the current consumption by harvesting more, given that the marginal utility of consumption is diminishing. More amenities are produced instead. The same holds for future income, since given perfect capital markets, the current and future income have similar impacts on the present value of the life-time income. As a corollary, it may be noted that both consumption and amenities are normal goods, i.e. the demand for both increases with income (c_I, $K_I > 0$).

Using the result for exogenous income, the income effects of other factors can also be signed. An increase in the *current stumpage price* has a positive compensated effect related to an increase in the marginal revenue of the current harvest. The income effect is negative. As an increase in the stumpage price implies a higher income at any given quantity of timber sold, the forest owner becomes less willing to increase his/her current consumption by harvesting more. Thus, the total effect in (6.8b) remains ambiguous. The effect of an expected increase in the *future stumpage price*, in (6.8c), is unambiguously negative. As the marginal opportunity cost of the current harvest increases, the substitution effect is negative. The income effect also is negative, as the future income is expected to rise *ceteris paribus*.

The substitution effect of the *interest rate* is always positive. This is because an increase in the interest rate implies a higher stock holding cost (i.e., a higher opportunity cost for an increase in the future harvest or in the production of nontimber services). The income effect, however, may be either positive or negative. For positive net savings ($S > 0$), the income effect is negative since an increase in the interest rate implies a higher interest income in the future. The total effect in (6.8d) then remains indeterminate. For a net borrower ($S < 0$), a higher interest rate means a reduction in the disposable income after the interest charges. Consequently, a borrower is willing to harvest more to restore, in part, his/her current consumption level, and the total effect is positive.

The *initial stock of timber* has a positive compensated effect (Appendix 7). Rather than changes in the marginal revenue and cost, this now relates to the substitution between marketed goods and nonmarket amenities (loosely speaking, a larger initial stock allows the forest owner to harvest more while still retaining a high level of stock-dependent amenities). On the other hand, a greater initial endowment means a higher wealth and thereby has a negative income effect. As the marginal utility of consumption is diminishing, part of the additional standing stock is held for nontimber purposes.

Concluding remark

The comparative statics results differ in certain respects from the basic model with only timber values considered (Chapter 3). The results can be summarized as

$$(6.8') \quad H = H(\underset{?}{p_1},\ \underset{-}{p_2},\ \underset{?/+}{r},\ \underset{-}{I},\ \underset{?}{Q}).$$

The effect of current stumpage price, for example, is *a priori* uncertain because of opposite substitution and income effects. Empirical evidence suggests that the positive substitution effect dominates in practice, and the same seems to be true for the interest rate (see end note 7, Chapter 3). Notably, the effect of the initial stock also differs from the separation case. Rather than a unitary scale effect, the present model suggests that the effect is not only less than one but *a priori* uncertain in sign. Regarding NIPF owners in Scandinavia, at least, the present result seems to be more consistent with empirical findings (end note 7, Chapter 3). The latter suggest that while the positive compensated effect dominates, the elasticity of timber supply with respect to the timber inventory for one reason or the other is well below one.

While, theoretically, the nontimber considerations tend to reduce timber harvesting in the short run, their consequences on aggregate timber supply should be considered with caution. First, the effect on timber harvesting is likely to be of major importance for only small forest properties. This is because forest stands located near the house or second home are of most importance from the scenic point of view, and consequently the relative share of forest land subject to restricted timber harvesting due to scenic considerations, for example, is higher on small properties. (In Finland, for example, the mean annual harvest on the smallest woodlots, with less than 10 hectares of forest land, has been lower than in other size classes both in cubic meters and as a proportion of the allowable cut; Järveläinen 1988, Karppinen & Hänninen 1990). Secondly, the nontimber considerations result in a larger growing stock per unit area. Within reasonable limits (up to the MSY level), this implies an increase in timber growth and sustainable harvest, or potential supply, over time.[5]

6.3 Effects of forest taxes: a positive analysis

The effects of alternative forest taxes are now analyzed to see how the results change when nontimber management objectives are introduced. As in Chapter 4, lump-sum, yield, and *ad valorem* property taxation are dealt with. Note that management costs are not considered, so the results for yield taxation will correspond to the case where costs are fully deductible. Therefore, the specific label *profit* tax will be used below for clarity.

The formal decomposition procedure is not repeated. This is because the effects of the forest taxes (as well as the capital income tax) are directly comparable to those of the exogenous income, stumpage prices, and the interest rate in section 6.2. Also, because the ultimate interest is on the relative efficiency of taxes, only the substitution effects matter (see section 5.1.1 and

Appendix 2). These effects, in fact, can readily be understood by considering the first-order conditions with the marginal utility of consumption held unchanged. Once only changes in relative prices matter, the optimal forest tax regime (section 6.4) can be solved by simply using the optimality conditions with the terms $u'(c_i)$ treated as constants (see Appendix 7).

The optimization problem generally remains the same as that in (6.1) through (6.4). The only difference appears in the budget constraints. With all relevant taxes simultaneously written down, these become

$$(6.9a) \quad c_1 = (1 - \pi_1)p_1H_1 + I - S - \Lambda_1 - \alpha_1 p_1 K_1$$
$$(6.9b) \quad c_2 = (1 - \pi_2)p_2H_2 + (1 + r)S - \Lambda_2 - \alpha_2 p_2 K_2,$$

where Λ, π and α denote the lump-sum, profit, and *ad valorem* property taxes, respectively, and K_1 and K_2 are as in (6.2). Given the intertemporal budget constraint

$$(6.10) \quad c_2 = (1 - \pi_2)p_2H_2 + (1 + r)[(1 - \pi_1)p_1H_1 + I - \Lambda_1 - \alpha_1 p_1 K_1 - c_1] - \Lambda_2 - \alpha_2 p_2 K_2,$$

the first-order conditions for an interior solution become

$$(6.11a) \quad V_{c_1} = u'(c_1) - \beta u'(c_2)(1 + r) = 0$$
$$(6.11b) \quad V_{H_1} = \beta u'(c_2)\{(1 + r)[(1 - \pi_1)p_1 + \alpha_1 p_1] + (1 + F')\alpha_2 p_2\} - \beta v'(K_2)(1 + F') - v'(K_1) = 0$$
$$(6.11c) \quad V_{H_2} = u'(c_2)[(1 - \pi_2)p_2 + \alpha_2 p_2] - v'(K_2) = 0.$$

To illustrate the *substitution effects* of taxes, "cutting rules" similar to (6.7) are used with the terms $u'(c_i)$ treated as constants. For *income effects*, the result in (6.2) for the exogenous income in (6.2) is used. Denoting the substitution effects by the compensated supply function $H^c(.)$ and total responses by the ordinary supply $H(.)$, the results can be summarized as follows:

$$(6.12a) \quad H^c = H^c(\underset{0}{\Lambda};\ \underset{-}{\pi_1},\ \underset{+}{\pi_2},\ \underset{-}{\pi};\ \underset{+}{\alpha_1/\alpha},\ \underset{0}{\alpha_2})$$
$$(6.12b) \quad H = H(\underset{+}{\Lambda};\ \underset{?}{\pi_1},\ \underset{+}{\pi_2},\ \underset{?}{\pi};\ \underset{+}{\alpha_1/\alpha},\ \underset{+}{\alpha_2}).$$

The lump-sum tax

According to (6.9), the lump-sum tax Λ_i is equivalent to an equal reduction in the exogenous income in period i. As relative prices remain unaltered, there is only an income effect which is obviously positive: given a reduction in disposable income, the forest owner is willing to harvest more to restore in part his/her consumption level. (The lack of substitution effects also shows in that the optimality conditions become similar to the untaxed case (6.7), except that Λ is included in the argument of $u'(c_i)$. When considering substitution – i.e., compensated – effects, however, any impacts due to changes in c_2 are ignored). Recalling (6.10), an increase in Λ reduces the life-time consumption possibilities or c_2. Given $u'' < 0$, $u'(c_2)$ in (6.7) then increases. Consequently, the R.H.S. increases so that $F' = F'(K_1)$ and $v'(K_1)$ must increase to restore the equilibrium. The latter (with $F'' < 0$, $v'' < 0$) implies a lower growing stock ($K_1 = Q - H$) and an increase in the current harvest. In other words,

$$(6.13) \quad H_{\Lambda_1} = -H_1 > 0, \quad H_{\Lambda_2} = -(1 + r)^{-1}H_1 > 0, \quad H_{\Lambda} > 0,$$

or the lump-sum tax increases the current harvest whether the tax rate varies or remains constant over time.

The profit tax

The effects of the remaining taxes now become readily tractable as it is noted that, first, the *substitution effects* are equivalent to changes in the stumpage prices or the interest rate (section 6.2). Secondly, the *income effects* always work in the same direction as the lump-sum tax, i.e. both current and future income effects are positive for all the taxes. For the substitution effects of the *profit tax*, consider

$$(6.14) \quad \frac{(1 - \pi_2)p_2}{(1 - \pi_1)p_1}(1 + F') = (1 + r) - \frac{v'(K_1)}{(1 - \pi_1)p_1 \beta u'(c_2)}.$$

According to (6.14), the stumpage prices $p_i (i = 1,2)$ are replaced by the after-tax prices $p_i(1 - \pi_i)$. In other words, the profit tax is equivalent to a reduction in the relevant period's stumpage price. For compensated effects alone, an increase in π_1 tends to reduce while π_2 increases the current harvest. Assuming $\pi_1 = \pi_2 = \pi$, the expressions $(1 - \pi_i)$ on the L.H.S. cancel out and π only appears on the R.H.S. As π reduces the R.H.S., $F'(.)$ and $v'(K_1)$ must be reduced to restore the equality. The latter requires a greater growing stock so the current harvest must decline. Thus, even an invariant profit tax has a negative substitution effect so that $H^c_{\pi_1} < 0$, $H^c_{\pi_2} > 0$, and $H^c_\pi < 0$. As the income effects are always positive, the total effects can be stated as

$$(6.15)\quad \begin{aligned} &\text{sgn } H_{\pi_1} = -\text{sgn } H_{p_1} \lesseqgtr 0,\\ &\text{sgn } H_{\pi_2} = -\text{sgn } H_{p_2} > 0,\\ &\text{sgn } H_\pi = -\text{sgn } H_p \lesseqgtr 0. \end{aligned}$$

The ad valorem property tax

The corresponding cutting rule under the *ad valorem* property tax becomes

$$(6.16)\quad \frac{p_2}{p_1}(1 + F') = (1 + r)(1 + \alpha_1) - \frac{v'(K_1)}{\beta u'(c_2)p_1}.$$

By (6.16), the substitution effect is equivalent to an additive increase in the interest rate, at a rate approximately equal to the tax rate, as $(1 + r)(1 + \alpha_1) \approx 1 + (r + \alpha_1)$. Alternatively, dividing through by $(1 + \alpha_1)$ shows that it is equivalent to a multiplicative increase in the current stumpage price at the rate of α_1 (cf. Chapter 4). As α increases the R.H.S. in (6.16), F'(.) and $v'(K_1)$ must increase, which implies that more will be cut today. In other words, sgn $H^c_{\alpha_1}$ = sgn H^c_α = sgn $H^c_r > 0$. The income effects, in contrast, are not equal with the interest rate but unambiguously positive for all cases so that

$$(6.17)\quad H_{\alpha_1} = H_\alpha > 0,\quad H_{\alpha_2} > 0.$$

The *ad valorem* property tax will unambiguously increase the short-run timber supply, since both compensated and income effects are positive for the current tax as well as an intertemporally invariant tax rate. Unlike the basic case, an anticipated change in the future tax rate also has a qualitatively similar impact due to a positive income effect.

6.4 Efficient forest taxation: a normative analysis

This section turns to the relative efficiency of forest taxes in the presence of nontimber objectives. As earlier, the distinction between an initially undistorted economy and one with a pre-existing capital income tax will be central to the analysis.

The conditions for a socially optimal allocation now involve the marginal valuation of the standing stock to represent the production of nontimber services, as shown in section 6.2. As regards the representative private forest owner, however, it is not clear whether the nontimber considerations will be taken into account or not. Since both possibilities can be argued, two cases will be considered in the normative analysis below.

(1) The representative forest owner's and the policy-maker's preferences with respect to consumption (income) and nontimber benefits are first assumed to be identical (section 6.4.1). That is, the policy-maker as a social planner "must be" interested both in income and environmental values, while the forest owner himself derives utility from the forest's nontimber services and therefore takes them into account. The latter assumption is plausible with respect to a NIPF owner who regularly lives on the property or uses it as part-time residence. (Assuming the opposite in this case might amount to arguing that a forest owner's preferences, for some reason, inherently differ from other people's).

(2) Alternatively, it is assumed that the nontimber services, while socially valued, are completely ignored by the private forest owner (section 6.4.2). This follows the argument that the environmental benefits, as an externality with no compensation to the landowner, will be underproduced. This might be a reasonable assumption in the case of corporate owners, as well as NIPF owners who live off the property without even using it as a part-time residence.[6]

Due to the nonseparability of harvesting and consumption decisions, taxes now have income effects in addition to the compensated or substitution effects. As established earlier, only substitution distortions matter for the relative efficiency of alternative taxes while the income effects can be ignored. To anticipate the results, this implies that where (a) nontimber benefits are taken into account by both the forest owner and the policy-maker and (b) distortions from other taxes do not pre-exist, efficiency calls for a forest tax regime with no substitution effects. If the opposite is true in both respects, the proper tax rate should not only offset the initial tax distortion but also internalize the social valuation of nontimber benefits.

6.4.1 Identical private and social valuations

Consider a "symmetric" case where the policy-maker and the representative forest owner have identical preferences over income and non-income benefits. (The opposite symmetric possibility was represented by the basic case where neither party was assumed to pay "special attention" to nontimber values; this can be re-interpreted as a situation where the standing forests are so abundant that the marginal utility from an increase in their environmental services tends to zero). Focusing on the substitution effects alone, and accordingly omitting the effects due to changes in the consumption level, means that the intertemporal budget constraint c_2 remains unchanged. Thus, as in Chapter 5, the optimal forest tax regime can simply be found by considering the private and socially optimal cutting rules with the marginal utilities $u'(c_2)$, as well as $u'(c_1)$ and $v'(K_2)$, treated as given quantities (see Appendix 7). As the solution is reduced to one equation, only one unknown can be solved at a time so the relevant tax rate must be constant over time.

No pre-existing distortions

The socially optimal cutting rule for the stationary case ($p_1 = p_2 = p$) becomes

$$(6.18)\quad (1 + F') = (1 + r) - \frac{v'(K_1)}{p\beta u'(c_2)}.$$

Next, the private cutting rules with the forest taxes and without/with the capital income tax τ are developed in a similar form. Simultaneously inserting all relevant forest taxes, the private solution can be written as

$$(6.19)\quad (1 + F') = (1 + r)(1 + \alpha) - \frac{v'(K_1)}{(1-\pi)p\beta u'(c_2)}.$$

Equating the R.H.S. with the R.H.S. of (6.18) yields

$$(6.20)\quad (1 + r)(1 + \alpha) - \frac{v'(K_1)}{(1-\pi)p\beta u'(c_2)} = (1 + r) - \frac{v'(K_1)}{p\beta u'(c_2)}.$$

According to (6.20), first, the *lump-sum tax* is consistent with efficiency. By the assumption of identical preferences, the terms $u'(c_2)$ and $v'(K_1)$ on both sides are equal. With $\pi = \alpha = 0$, (6.20) holds irrespective of Λ, so that the private and social optima coincide. Secondly, for the other taxes $\pi = \alpha = 0$ is the only tax rate at which (6.20) can hold.[7] Thus, the *profit* or *ad valorem property taxes* cannot be efficient.

In conclusion, only lump-sum taxes, such as the unmodified site productivity tax, are consistent with efficiency given that the economy is initially undistorted and the nontimber values matter both to the policy-maker and the forest owner. Compared to Chapter 5, note that the profit tax no longer is efficient. This is because the profit tax, even when constant, now has a (negative) substitution effect, which an appropriate forest tax in this case should not have.

Distortionary capital income taxation

As shown in Chapter 5, the interest rate r is replaced by $r(1 - \tau) < r$, if the income from other assets is taxed and/or the interest charges for loans are tax deductible. That is, the capital income tax τ is equivalent to a reduction in the interest rate. According to (6.8d), the following therefore holds for its compensated and total effects in the presence of nontimber objectives:

$$(6.21)\quad \begin{aligned} &\text{sgn } H^c_\tau = -\text{sgn } H^c_r < 0\\ &\text{sgn } H_\tau = -\text{sgn } H_r \overset{=?}{<0} \text{ as } S \gtrless 0. \end{aligned}$$

Since the capital income tax has a negative substitution effect on the short-run timber supply, the appropriate forest tax should accordingly encourage the realization of timber to offset the distortion. (Interestingly, it can be shown that even the expenditure taxation (see Appendix 4) in this case would not be without substitution effects. This is because the consumption of marketed goods is taxed, while the nonmarket amenities are not). The counterpart to (6.20) now becomes

$$(6.22)\quad [1 + r(1 - \tau)](1 + \alpha) - \frac{v'(K_1)}{(1-\pi)p\beta u'(c_2)} = (1 + r) - \frac{v'(K_1)}{p\beta u'(c_2)}.$$

It can readily be seen that *lump-sum taxes*, with no substitution effects, can not be efficient in the presence of capital income taxation. Setting $\alpha = \pi = 0$ implies $1 + r(1 - \tau) = 1 + r$, which is untrue given $\tau > 0$. For the *profit tax*, the solution can be written as

$$(6.23)\quad \pi = 1 - \frac{v'(K_1)}{v'(K_1) - r\tau p\beta u'(c_2)} \begin{smallmatrix}<0\\>1\end{smallmatrix} \quad \text{as } v'(K_1) - r\tau p\beta u'(c_2) \gtrless 0.$$

The profit tax clearly cannot be used as a corrective tax, as the solution suggests meaningless tax rates that are negative or greater than one hundred per cent.[8] In fact, that the profit tax amplifies rather than offsets the initial inefficiency could be expected, as it was shown to have a negative compensated effect on the current harvest – i.e., work in the same direction with τ – even when constant over time.

Again, efficiency can be attained by the *ad valorem property tax*. The appropriate property tax rate to offset the initial distortion becomes

$$(6.24) \quad \alpha = \frac{r\tau}{1 + r(1-\tau)} \approx r\tau,$$

i.e. the interest rate multiplied by the capital income tax rate. The result is equivalent to the case of a pre-existing capital income tax with no nontimber considerations.

6.4.2 Asymmetric valuations

This section considers an "asymmetric" case where the policy-maker (society) does value the nontimber benefits but the forest owner does not take them into account. In other words, the representative forest owner is now assumed not to derive utility from the nontimber services. As the latter are provided as an externality, with no compensation for providing them, the forest owner then behaves as if the marginal utility of the standing stock were zero. The policy-maker, on the other hand, perceives the marginal social value of the standing stock as positive and wishes to induce the forest owner to behave in a socially optimal manner by choosing an appropriate forest tax regime (cf. pigouvian forest taxes in Englin & Klan 1990).

No pre-existing tax distortions

Setting $v'(K) = 0$, the private solution reduces to a separation result similar to the basic model. The socially optimal cutting rule is the same as in section 6.4.1. For an initially undistorted economy, the counterpart to (6.20) and (6.22) becomes

$$(6.25) \quad (1 + r)(1 + \alpha) = (1 + r) - \frac{v'(K_1)(1 + r)}{pu'(c_1)},$$

because Λ has no substitution effects at all and π with a constant tax rate vanishes in the separable private cutting rule. By (6.25), neither the lump-sum nor the profit tax can induce the forest owner to appropriately change his/her behavior. The private optimum under lump-sum or profit taxation implies a marginal product of the growing stock in excess of that at the social optimum. The standing stock and provision of amenities thereby remain lower than socially optimal.

Interestingly, the result that the profit tax fails to attain efficiency contrasts with the contention (e.g. Heaps & Helliwell 1985, Gamponia & Mendelsohn 1987) that yield taxes, as they lengthen forest rotations, are more sympathetic with the forest's nonmarket services. Suppose the reason why forest taxation *should* extend rotations is that private forest owners tend to ignore nontimber values. Then, however, the *profit tax* cannot really contribute to this aim, since a (constant) profit tax is in fact neutral in the case of profit-maximizing forest owners. For the *gross* yield tax, there might be a point in the argument, but no rigorous proof seems to have been presented.

For the *ad valorem* property tax, the solution

$$(6.26) \quad \alpha = -\frac{v'(K_1)}{pu'(c_2)} < 0$$

is obtained. This suggests that the corrective "property tax rate" should be negative; that is, inducing the private forest owner to choose a larger growing stock and provide more nontimber services would call for an "environmental subsidy". This, however, violates the requirement of a positive tax revenue. In summary, none of the taxes under consideration can be used as a corrective tax in this case.

Distortionary capital income taxation

Given the capital income tax, (6.25) is replaced by

$$(6.27) \quad [1 + r(1-\tau)](1 + \alpha) = (1+r) - \frac{v'(K_1)(1 + r)}{pu'(c_1)}.$$

The capital income tax (as far as substitution effects are concerned) reduces timber harvesting and implies a higher growing stock, which in this case contributes to bringing the private solution closer to the social optimum. While the two occasionally coincide at $\tau = v'(K_1)(1 + r)/rpu'(c_1)$, the resulting stock may generally be greater or smaller than socially optimal.

Regarding forest taxes, the lump-sum or profit taxes cannot contribute to make the private and social optima coincide, since Λ and π do not appear in (6.27). For the *ad valorem* property tax, the solution becomes

$$(6.28) \quad \alpha \approx r\tau - \frac{v'(K_1)(1 + r)}{pu'(c_1)} \gtrless 0,$$

which can be compared to the solution $\alpha \approx r\tau$ for the symmetric cases. In principle, a property tax rate can be found that offsets the net distortion from the capital income tax, on the one hand, and from the ignorance of nontimber values by private owners, on the other. The required tax rate is equal to the interest rate multiplied by the capital tax rate *minus* the ratio of the marginal utility of timber in consumption and its marginal utility as an *in situ* resource. The suggested rate is always lower than in the earlier cases. As a practical tax policy, however, the solution is not without problems. It is not clear *a priori* whether α should be positive or negative. Further, it depends not only on the values of r and τ but also on the social marginal valuation between the forest-related amenities vs. the consumption of marketed goods. This not directly observable, and may be only vaguely quantifiable.

6.5 Conclusion

At this point, it is useful to summarize the results concerning the relative efficiency of forest taxes. To give an overall view of all cases considered, Table 1 indicates the appropriate forest tax base and tax rate, if any, under alternative assumptions concerning the presence of capital tax distortions as well as nontimber considerations.

Table 1. Summary of economically efficient forest tax regimes under alternative assumptions. Λ, π and α denote lump-sum, profit, and *ad valorem* property taxes, κ is the accrual income tax, and $R = 1 + r$.

	Only timber matters	Nontimber benefits valued by: pol.maker only	Nontimber benefits valued by: both
No tax distortions pre-exist	Λ, $\pi_1 = \pi_2$	none	Λ
Distortionary capital inc. taxation	$\alpha \approx r\tau$ ($\kappa = \tau$)	$\alpha \approx r\tau - \frac{Rv'(K_1)}{pu'(c_1)}$[1]	$\alpha \approx r\tau$

[1]Applies where $\alpha > 0$

Consider the extreme left and right hand columns. In these "symmetric" cases, either the monetary income from merchantable timber alone is considered or the nontimber services also are uniformly valued by both the policy-maker and the forest owner. For both possibilities, the following three conclusions hold:

(1) Where no tax distortions pre-exist, lump-sum taxes, such as the unmodified site productivity tax or the site value tax, are efficient regardless of the tax rate;
(2) Given a distortionary capital income tax, an *ad valorem* property tax levied on the value of standing timber at the rate $\alpha \approx r\tau$ will attain efficiency;
(3) The yield or realized income taxes are generally not consistent with efficiency, the sole exception being a stable profit tax in the case of no initial distortions or nontimber considerations.

In the case of no pre-existing distortions, other neutral taxes, such as the profit tax at an invariable tax rate, are also efficient where the nontimber values do not matter. However, the profit tax is no longer optimal, if the nontimber considerations are taken into account or if a capital income tax pre-exists. In the latter case, efficiency calls for a property tax with a rate set to offset the capital income tax. Alternatively, efficiency could be attained by an accrual income tax, where the net gain in property value is taxable income. In contrast, *realized* income taxes are inappropriate in the presence of an income tax on other assets. On the other hand,

(4) In the "asymmetric" case where the nontimber benefits are ignored by the forest owner, lump-sum or profit taxes cannot attain efficiency, while the *ad valorem* property tax may be appropriate in the presence of capital income taxation.

A problem with the latter case is that the correct property tax rate is theoretically uncertain in sign. Practically, a plausible approximate solution might be a positive tax rate somewhat lower than that required to fully offset the distortions with timber production considered alone. Even without nontimber considerations, feasible property tax rates would usually have to be lower than the "fully corrective" rates (Appendix 5 and end note 9, Chapter 7). That is, the latter are to be taken as suggestive rather than literally for practical policy considerations.

Notes to Chapter 6

[1]Johansson *et al.* (1989) show the externality-induced market failure by assuming that the forest owner is interested in income only while other consumers also derive utility from the environmental services. Binkley (1981, 1987), Kuuluvainen (1985, 1986), Royer (1987), Max and Lehman (1988), and Dennis (1989) assume that the nontimber values also matter to the NIPF owner (Hyberg & Holthausen (1989) develop zero restrictions to test the hypothesis). There is suggestive evidence that nontimber values matter to NIPF owners. According to Carlén (1990), one third of forest owners ranked nonmonetary goods as their most important objective. In Finland, many small forest holdings are mainly used for purposes other than timber production (Järveläinen 1988, Karppinen & Hänninen 1990). According to Ihalainen (1992), timber income and other monetary objectives were ranked highest by 2/3 of forest owners, and recreation or other nonmonetary objectives by about one third.

[2]Following Hartman (1976) or Berck & Bible (1984) (also Strang 1983, Hite *et al.* 1987, Johansson & Löfgren 1988, Johansson *et al.* 1989), known shadow prices could be assumed to illustrate the potential difference between socially optimal and private harvest patterns. Here, a different approach is chosen in order to highlight the fact that given no actual compensation for producing amenity services, it depends on the forest owner's subjective preferences whether such considerations will be taken into account. Assuming known money measures would also conceal the nonseparation of harvesting and consumption decisions and the related income effects.

[3]Kellomäki & Savolainen (1984; also Savolainen & Kellomäki 1981, 1984) measured the scenic value of forest stands by the so-called adjective sum. Pukkala *et al.* (1988), in addition to scenic preferences, studied the recreational value of forest stands using beauty and recreation scores on a 10-point rating scale (for Scenic Beauty Estimation, see Daniel *et al.* 1989).

[4]If the mean diameter is used to represent tree size, the amenity of a forest could be written as $v = v(K,d)$ with v_K, $v_d > 0$, where K and d denote the standing volume and mean diameter, respectively. Harvesting affects both the standing volume and mean diameter of the remaining trees, i.e. $K = K(H)$, $K'(H) < 0$, and $d = d(H)$. However, the direction of change in the mean size of remaining trees depends on the specific cutting practice. Intuitively, $d'(H) > 0$ for thinnings from below but $d'(H) < 0$ for thinning from above, selective harvesting, or final fellings in the oldest age classes of a forest.

[5]The long-run timber supply will not be formally considered. This is because where the imputed utility from the standing forest also matters, a maximum supply of timber alone has no normative status for the subsequent tax analysis. Also, the long-run supply could not be so simply analyzed. As the objective function is no longer linear in the quantity harvested (the marginal utility of consumption is endogenous to the solution rather than a given constant), the optimal first-period harvest does not imply an immediate, 'bang-bang' adjustment to an optimal steady state stock. While a steady state with the harvest equal to forest growth intuitively exists, it may not be reached within a finite time horizon.

[6]For a closer look at the 'public goods' aspect, several (groups of) individuals, with different willingnesses-to-pay, should be considered. Because a single representative forest owner is considered here, the polar difference between private and social valuations must be used as a short-cut presentation. A third set of assumptions could also be derived. The nontimber considerations, in part incompatible with timber production, have sometimes been considered as a threat to the availability of industrial wood. Following this, the forest owner would behave as if the standing stock had a positive marginal utility, while from the policy-maker's point of view there is no need to adjust harvesting decisions. However, this case is omitted. It is not particularly well-argued, and the tax results, in broad terms, would be similar to those in section 6.4.2 with a reversed sign on the marginal social value of the standing stock.

[7]If the profit and property taxes could be used in combination, (6.20) could be solved for the optimal α with π fixed, or *vice versa*. Using (6.5b) and (6.5c), the solution with respect to α eventually simplifies to $\alpha = \pi(r - F')/(1 - \pi)(1 + r)$, with $\alpha > 0$ as $F' < r$.

[8]While the denominator of the latter term (B) cannot be signed *a priori*, it can be noted that $r \tau p \beta u'(c_2) > 0$ so the denominator is less than the numerator. Thus, whenever $v'(K_1) - r \tau p \beta u'(c_2) > 0$, the quotient (B) must be greater than one in absolute value so that $1 - B < 0$. If the denominator is negative, it follows that $1 - B > 1$.

7 Forest taxation in Finland

This chapter analyzes the forest tax issues specific to Finland. The purpose is twofold. Theoretically, first, this provides an example of actual forest tax systems that may be rather more complicated than the stylized representation of the main tax types suggests. It is also shown that tax subsidies, while augmenting timber production in the long run, may result in an inefficient allocation. Secondly, the analysis is of direct relevance to the forest tax policy in Finland. The effects of the new instruments introduced within the site productivity taxation in 1991 have not been properly established. Further, the proposal of a switch to realized income taxation in forestry seems to ignore the issue of economic efficiency or, at least, fails to consider the effects of the tax system as a whole.

Section 7.1 first outlines the major forest tax issues, capital income taxation, and forestry situation in Finland. The effects and efficiency of the modified site productivity taxation, as it stands after the 1991 reform, is analyzed in section 7.2. Section 7.3 considers the realized income tax which is to be introduced in 1993. Numerical examples are provided to illustrate the magnitude of the resulting management distortions. Section 7.4 concludes the chapter and points out forest tax regimes that can attain efficiency under a pre-existing capital income taxation.

7.1 Recent tax issues and forestry

Since 1922, forest taxation in Finland has been based on site productivity. The system was initially close to the unmodified site productivity tax, where the taxable income is determined by the estimated mean annual yield by site quality irrespective of the actual harvest and timber stocking. Criticism has been concerned with the level and allocation of the tax burden, since the average taxable income may not fully reflect the actual short or medium-term income-earning capacity of individual woodlots. Recently, it has been suggested that the aggregate taxable income may become overestimated as the annual timber growth exceeds the annual harvest level and all timber grown has not been or can not be realized. On the other hand, even if one of the main arguments for site productivity taxation has been the lack of disincentive effects on intensive forest management, suggestions have been made that forest taxation be designed to more actively encourage the use of forest resources (e.g. Puuhuollon … 1985).[1]

Two contradicting trends have recently emerged. One is represented by a committee on forest taxation (Metsäverotoimikunta … 1988), which scheduled several changes within the site productivity taxation. In part, the reform was motivated by equity arguments, such as reallocating the tax burden by the actual harvest potential of individual woodlots and taking into account the actual realization possibilities at the aggregate level. Another purpose was to encourage the use of timber resources, especially the final harvesting and regeneration of mature stands. Accordingly, in 1991 the tax allowance for established seedling stands, applied since 1980, was extended to a tax exemption starting at the time of regeneration. Tax deductions for management costs were also introduced to subsidize reforestation, brush control and precommercial thinnings in seedling stands, as well as first commercial thinnings in juvenile stands (Laki maatilatalouden … 1990). After the 1991 reform, the Finnish forest tax system can no longer be represented by a lump-sum tax, and will be referred to as "modified" site productivity taxation.

As another trend, a switch to some form of realized income taxation has been repeatedly suggested. A sales tax with special arrangements to alleviate the effects of progressive taxation was discussed in the late 1970's (Metsäverotuksen … 1978, Korpinen 1978). In 1989, a proportional realized income tax with immediate expensing was considered by another committee (Puukaupan … 1989). Recently, the realized income taxation has appeared in a new setting. A committee on the harmonization of capital income and corporate taxation (Pääomatulojen … 1991) proposed a uniform proportional tax rate to be applied to the realized income from forestry, as well as all other capital income. More detailed regulations for forestry taxation were subsequently proposed (Puun myyntitulojen … 1992), and the new regime is to be introduced in 1993.

Two notes on the background conditions and institutional setting should be made. The first one has to do with the state of capital markets and capital income taxation. Owing to rationed nominal interest rates combined with high rates of inflation, the real interest rates used to be low and even negative, which was the case during most of 1970's, for example. (On the other hand, credit rationing tendencies were typical of the capital market). Further, most of interest charges on loans – 75 % in the early 1990's – have been tax deductible, thus reducing the effective cost of borrowing through the marginal tax rate. Under these conditions savings are discouraged. There is a lock-in effect on the realization of inflation-safe assets such as timber, and the substitution of bank loans for internal funding, from stumpage sales for example, is encouraged.

Since the mid-80's, there has been a gradual deregulation of the capital market. The switch towards market-determined and significantly higher interest rates, combined with a reduction of inflation, has established positive real interest rates. (In the early 1990's, the real interest rates have been exceptionally high). However, the distortionary tax treatment of capital income and interest charges remains. According to the scheduled reform (Pääomatulojen ... 1991), interest charge deductions will continue to be allowed at the uniform 25 % capital income tax rate (but without quantitative limitations). On the other hand, the 25 % tax rate on interest income is significantly higher compared to the 10–15 % level in the early 1990's. Thus, pre-existing distortions from capital income taxation continue to be an important background issue when the efficiency of forest taxation in Finland is considered.

Another background factor worth noting is Finland's forestry situation. During the last two decades, Finland has undergone a transition from a threatening timber shortage to what has been called the "excess production" of timber: the annual timber growth significantly exceeds the annual harvest and wood-using capacity of the forest industries, and there is an increasing surplus of mature timber stands especially in southern Finland (Puuhuollon ... 1985, Yearbook of ... 1989, Metsäsektorin ... 1991). For example, the annual cut could be almost doubled for the next two decades without reducing the potential harvest below the current levels (see Metsä 2000 -ohjelman ... 1992). Thus, the practical main forestry issue is the use of the existing timber inventory, while the long-run supply is unlikely to effectively restrict the annual timber harvest in the foreseeable future (reaching a steady state with the annual harvest equal to timber growth would call for a major expansion in the wood-using industry).

Accordingly, the analysis of timber supply in this chapter refers mainly to the "short-run" type of supply, as defined earlier. This is in line with the theoretical point (Chapter 5) that the long-run supply has no normative status where initial distortions from capital income taxation exist. (Furthermore, the modified site productivity taxation involves explicit management subsidies that increase timber production in the long run, but generate an excess burden).

7.2 The modified site productivity taxation

This section considers the site productivity taxation of forests in Finland after the 1991 reform (Laki maatilatalouden ... 1990). The relevant taxes as a whole include the capital income tax and several variables for specific forest tax items as follows:

(1) A proportional *capital income tax*, at rate τ, represents both the tax on interest income and interest charge deductions. This corresponds to the proposed reform of capital income taxation, according to which a uniform tax rate will be applied symmetrically.

(2) The annual *site productivity tax* is based on the estimated taxable income, which in turn is determined by the value of mean annual increment by the forest site type class (soil productivity). As the taxable income from forestry is added to the owner's nonforest income, the actual productivity tax Γ_i to be annually paid depends on his/her personal marginal tax rate. Tax progression is not essential here, so the tax rate is denoted by the fixed income tax rate θ_i. Denoting the estimated mean annual yield and unit value of timber by $\hat{G}$ and $\hat{p}$, respectively, the annual productivity tax is $\Gamma_i = \theta_i \hat{p} \hat{G}$.

(3) A *tax exemption for regeneration areas* is allowed for 5–10 years as soon as the reforestation measures are completed and for another 15–25 years after the seedling stand is shown to be well-established. Denoting the annual productivity tax by Γ (FIM/ha/yr) and the length of the tax exemption period due to a unit of timber harvested by ε (yr · ha/m^3), the money value of the tax exemption per unit of timber cut will be $x_i = \varepsilon_i \Gamma_i$ (FIM/m^3). That is, the marginal tax subsidy for regeneration areas is represented as a fixed amount x_i per cubic meter of timber harvested in period i.[2]

(4) Major *management costs* are tax deductible. A fixed deduction per hectare is made for reforestation measures (planting, seeding, or natural regeneration), as well as precommercial thinnings and/or brush control in seedling stands. This is represented as a fixed proportion δ of actual management costs, which is equivalent to subsidizing the silvicultural measures by this rate.

7.2.1 *Effects on timber supply and management intensity*

The effects of the tax system on timber supply decisions are analyzed using a setting similar to that employed in Chapters 3 through 5. That is, the management intensity is considered as endogenous, while the nontimber considerations are ignored for clarity.[3] Perfect capital markets and perfect foresights continue to be assumed as a purely analytic tool to exclude any income or liquidity effects (as discussed earlier, only the substitution effects of taxes are relevant from the efficiency point of view). Accordingly, the representative forest owner's budget constraints become

$$\text{(7.1a)}\quad \begin{aligned} c_1 &= p_1H_1 - S - wE - (\Gamma_1 - \varepsilon_1 \Gamma_1 H_1 - \delta wE) \\ &= (p_1 + \varepsilon_1 \Gamma_1)H_1 - S - \Gamma_1 - (1 - \delta)wE \end{aligned}$$

$$\text{(7.1b)}\quad \begin{aligned} c_2 &= p_2H_2 + [1 + r(1 - \tau)]S - (\Gamma_2 - \varepsilon_2 \Gamma_2 H_2) \\ &= (p_2 + \varepsilon_2 \Gamma_2)H_2 + [1 + r(1 - \tau)]S - \Gamma_2, \end{aligned}$$

where Γ_i is the site productivity tax (FIM/ha/yr) and ε_i represents the exemption for regeneration areas (yr · ha/m^3). Further, δ is the tax deductible proportion of management costs, τ denotes the capital income tax rate, and all other notation is the same as in Chapters 3 through 5. In what follows, the tax exemption (harvest subsidy per unit of timber) is represented by $x_i = \varepsilon_i \Gamma_i$ (FIM/m^3) and the capital income tax by $r(1 - \tau) = r^0$. The problem is

$$\text{(7.2)}\quad \underset{\{c_1, H, E\}}{\text{Maximize}}\ U = u(c_1) + \beta u(c_2)$$

$$\text{where}\quad \begin{aligned} c_2 = {} & (p_2 + x_2)[Q - H + F(Q - H, E)] \\ & + (1 + r^0)[(p_1 + x_1)H - \Gamma_1 \\ & - (1 - \delta)wE - c_1] - \Gamma_2. \end{aligned}$$

The separation of production decisions from consumption preferences continues to hold. The current harvesting and management intensity decisions are characterized by

$$\text{(7.3a)}\quad -(p_2 + x_2)[1 + F_K(.)] + (1 + r^0)(p_1 + x_1) = 0$$

$$\text{(7.3b)}\quad (p_2 + x_2)F_E(.) - (1 - \delta)w(1 + r^0) = 0,$$

which can be rewritten as the optimal cutting and investment rules

$$\text{(7.4a)}\quad \frac{p_2 + x_2}{p_1 + x_1}[1 + F_K(.)] = 1 + r^0$$

$$\text{(7.4b)}\quad \frac{p_2 + x_2}{(1 - \delta)w} F_E(.) = 1 + r^0.$$

In contrast to unmodified site productivity taxation, the site productivity tax is no longer neutral. This is because, according to $x_i = \varepsilon_i \Gamma_i$, the level of annual site productivity taxes Γ_i and the parameter ε_i together determine the marginal tax gain x_i due to an additional cubic meter harvested. According to (7.4), the latter is equivalent to an additive increase by x_i in the relevant period's stumpage price, which compares with the unit sales subsidy of Vehkamäki (1986) or with the unit tax of Koskela (1989a,b). The effect on the harvesting decision is not readily clear when the exemption is perceived as permanent: by (7.4a), both the current and future effective price are affected.

Capital income taxation

For a more detailed analysis, management intensity is restricted to the cases where the management cost deduction applies, i.e. reforestation and brush control. Accordingly, the cross-partial derivative of the growth function can be restricted to $F_{KE} \leq 0$ (cf. Chapter 3). First, the effects of the capital income tax can be stated as

$$\text{(7.5a)}\quad \begin{aligned} H_\tau = {} & D^{-1}(p_2 + x_2)[r(p_1 + x_1)F_{EE} \\ & - (1 - \delta)wF_{KE}] \substack{<0 \\ =?} \text{ as } F_{KE} \substack{= \\ <} 0 \end{aligned}$$

$$\text{(7.5b)}\quad \begin{aligned} E_\tau = {} & -D^{-1}(p_2 + x_2)[(1 - \delta)wF_{KK} \\ & - r(p_1 + x_1)F_{KE}] \substack{>0 \\ =?} \text{ as } F_{KE} \substack{= \\ <} 0. \end{aligned}$$

As noted earlier, the capital income tax tends to imply a delay in the realization time of timber and encourage investment in forestry through a reduction in the opportunity cost of capital. According to (7.5a), the effect on timber supply is unambiguously negative for $F_{KE} = 0$ but somewhat softened by the implicit subsidy effect on reforestation investment (the case of $F_{KE} < 0$). While the direct effect on forestry investment in (7.5b) is positive, there is a negative indirect effect, since final fellings are discouraged so that fewer hectares will be reforested.

Forest taxes

To consider the specific forest tax variables, recall that the harvest subsidy x_i is used to represent both the site productivity tax Γ_i and tax exemption rates ε_i, the effects of which have the same signs (x without subscript refers to the case $x_1 = x_2$). The effects on timber supply can be written as follows:

$$H_{x_1} = -D^{-1}(p_2 + x_2)(1 + r^0)F_{EE} > 0$$

$$H_{x_2} = D^{-1}(p_2 + x_2)[(1 + F_K)F_{EE} - F_E F_{KE}] \overset{<\,0}{=\,?} \quad \text{as } F_{KE} \overset{=}{<} 0$$

$$\text{(7.6a)} \quad H_x = D^{-1}(p_2 + x)[(F_K - r^0)F_{EE} - F_E F_{KE}]$$

$$\gtreqless 0 \text{ as } p_2 \lesseqgtr p_1 \text{ when } F_{KE} = 0,$$

$$\overset{=\,?}{>\,0} \text{ as } p_2 \lesseqgtr p_1 \text{ when } F_{KE} < 0$$

$$H_\delta = -D^{-1}(p_2 + x_2)(1 + r^0)wF_{KE} \geq 0 \text{ as } F_{KE} \leq 0.$$

Like a temporary increase in the stumpage price, the current tax subsidy x_1 will increase the current harvest. The result, however, only means that the exemption for regeneration areas, *when perceived to be temporary*, unambiguously encourages final fellings. The future tax subsidy x_2, in contrast, tends to reduce the current harvest similarly to an anticipated future price increase, so the effect of a *permanent* harvest subsidy remains *a priori* indeterminate. Even if the indirect effect is ignored ($F_{KE} = 0$), the sign of H_x depends on whether the forest owner expects the future stumpage price to be higher, equal to, or lower than the current price (cf. Vehkamäki 1986, Koskela 1989a,b). Formally, this is because $F_K - r^0 \gtreqless 0$ as $p_2 \lesseqgtr p_1$ according to the first-order conditions. With constant price expectations ($p_1 = p_2$), the direct effect on the current harvest vanishes, i.e. the terms $p_i + x$ in (7.4a) cancel out, and consequently $F_K - r^0 = 0$ in (7.6a).

In other words, when the option for a tax exemption is perceived as permanent, it is not clear whether it will in fact encourage final fellings. Intuitively, a marginal tax gain has little impact on the optimal harvest timing if cutting a given stand today or later only implies a few year's difference in its time of receipt. Reforestation subsidies, on the other hand, indirectly encourage final fellings ($H_\delta > 0$ as $F_{KE} < 0$).

For the management intensity decision, the results are

$$E_{x_1} = -D^{-1}(p_2 + x_2)(1 + r^0)F_{KE} \geq 0 \text{ as } F_{KE} \leq 0$$

$$E_{x_2} = -D^{-1}(p_2 + x_2)[F_E F_{KK} - (1 + F_K)F_{KE}] \overset{>\,0}{=\,?} \quad \text{as } F_{KE} \overset{=}{<} 0$$

$$\text{(7.6b)} \quad E_x = -D^{-1}(p_2 + x)[F_E F_{KK} - (F_K - r^0)F_{KE}]$$

$$> 0 \text{ when } F_{KE} = 0,$$

$$\overset{=\,?}{>\,0} \text{ as } p_2 \lesseqgtr p_1 \text{ when } F_{KE} < 0$$

$$E_\delta = -D^{-1}(p_2 + x_2)(1 + r^0)wF_{KK} > 0.$$

The results suggest that the tax exemption for regeneration areas will increase management intensity ($E_x > 0$ whenever the stumpage price expectations are not decreasing). Formally, both x_2 and x improve the profitability of investment similarly to an increase in the future price (x_1 has only an indirect effect). Practically, the result seems plausible, because receiving the exemption requires that the reforestation measures, as well as the subsequent brush control, are completed. Subsidizing management costs (δ) unambiguously increases management intensity through a reduction in the marginal cost of silvicultural measures. Assuming that the direct effects dominate over the indirect ones, the results can be summarized as

$$\text{(7.7a)} \quad H = H(\underset{+}{x_1}, \underset{-}{x_2}, \underset{?}{x}; \underset{+}{\delta}, \underset{-}{\tau})$$

$$\text{(7.7b)} \quad E = E(\underset{+}{x_1}, \underset{+}{x_2}, \underset{+}{x}; \underset{+}{\delta}, \underset{+}{\tau}).$$

Maybe surprisingly, the harvest subsidy (x) may not have the expected effect on the short-run timber supply. The impact may vanish because the permanent option for a tax exemption effectively subsidizes both current and future final fellings. In fact, it has been suggested earlier that the allowance for established seedlings stands, in its original form, might only encourage the management of seedling stands rather than final fellings (Puuhuollon ... 1985, Tikkanen & Vehkamäki 1987), and the exemption was therefore proposed to begin at the time of regeneration. The present analysis suggests, however, that even then the desired effect on harvest timing may not be achieved. Finally, note that the above analysis formally dealt with "short-run" timber supply. However, as discussed in section 7.1, the results are relevant for quite a long time span given the forestry situation in Finland. For the effects on long-run steady state supply, see Appendix 8.

7.2.2 *Efficiency under capital income taxation*

Next to be analyzed is the economic efficiency of the modified site productivity taxation, given a capital income tax (interest charge deductions). Using the procedure developed in section 5.3, this section considers whether the tax system as a whole can attain the intertemporal efficiency of investment within forestry and the intersectoral efficiency between forestry and other sectors. The socially optimal allocation of investment is characterized by the following undistorted optimality conditions, similar to (5.10), with respect to the growing stock and other capital inputs in forestry:

$$\text{(7.8a)} \quad 1 + F_K(.) = 1 + r$$

$$\text{(7.8b)} \quad F_E(.) = (1 + r)(w / p).$$

According to (7.8), the marginal rate of return on the growing stock and investment in silviculture equals their social opportunity cost, or the pre-tax rate of interest representing the rate of return on investment in other sectors of the economy.[4] On the other hand, the private optimum conditions ($r^0 = r(1 - \tau)$, p = constant, and $x_1 \neq x_2$) are

$$\text{(7.9a)} \quad 1 + F_K(.) = (1 + r^0)\,\frac{p + x_1}{p + x_2}$$

$$\text{(7.9b)} \quad F_E(.) = (1 + r^0)\,\frac{(1 - \delta)w}{p + x_2}.$$

More specifically, the problem is whether the forest tax instruments appearing in the private solution, x_i and δ, can be appropriately set so as to offset the initial distortion from the capital income tax τ. As the private decisions are influenced by both capital income and forest taxes, the net effect of taxation is not readily visible in (7.9). For a closer analysis, the two sets of equations are used, as shown in Chapter 5. Given two equations, two unknowns can be solved, so the potential solution could be a combination of x_1 and x_2, with δ given. Alternatively, it could be a combination of a constant harvest subsidy x and δ. Equating the respective right-hand sides of (7.8) and (7.9) implies

$$\text{(7.10a)} \quad (1 + r^0)\,\frac{p + x_1}{p + x_2} = (1 + r)$$

$$\text{(7.10b)} \quad (1 + r^0)\,\frac{(1 - \delta)}{p + x_2} = (1 + r)/p.$$

Solving (7.10b) for $p + x_2$, substituting into (7.10a) and solving for x_1, the appropriate rates of the current and future period's tax subsidy become

$$\text{(7.11a)} \quad x_1 = -\delta p \leq 0 \text{ as } \delta \geq 0$$

$$\text{(7.11b)} \quad x_2 = p\left\{\frac{(1-\delta)[1 + r(1-\tau)]}{1+r} - 1\right\} < 0.$$

Surprisingly, the rate of harvest subsidy which is required to achieve efficiency is *negative* for both periods (the negativity of x_2 is because $1 + r(1 - \tau) < 1 + r$ and consequently $\{.\} < 0$). Rather than a positive harvest subsidy, the solution suggests that a *unit tax* on the timber harvested could be used to cancel out the effect of the capital income tax. However, note that $x_1 \neq x_2$ and, further, $x_2 = -\delta p - p(1 - \delta)r\tau/(1 + r) = x_1 - p(1 - \delta)r\tau/(1 + r)$. That is, the suggested unit tax is non-constant over time and the second-period rate is a function of the first-period rate, so the solution is practically irrelevant. Therefore, next consider if a combination of a time-invariable rate of x and δ could be used. With x constant, the counterpart of (7.10) becomes

$$\text{(7.12a)} \quad 1 + r(1 - \tau) = 1 + r$$

$$\text{(7.12b)} \quad [1 + r(1 - \tau)]\,\frac{(1-\delta)}{p + x} = (1 + r)/p.$$

Eq. (7.12a) is independent of the rate of x and implies $r\tau = 0$, which could only hold for $\tau = 0$, given $r > 0$. In other words, no rate of harvest subsidy (positive or negative) can offset the distortion from capital income taxation on the harvesting decision. Solving (7.12b) alone for x with δ fixed implies, as with (7.11b), that $x < 0$ for all $\tau \geq 0$, $\delta > 0$. Thus, a unit tax would be more consistent with efficiency than a harvest subsidy as far as the management intensity decision is concerned.

The result that the tax exemption may not work might seem unexpected (given that τ induces the forest owners to harvest "too little", one could expect that its impact could be offset by a harvest subsidy). The basic reason is that the option for a tax exemption is permanent. The incentive effect on a given period's final cut is therefore counteracted by the expectation that a tax gain is similarly obtainable in later periods, and the effect on harvest timing tends to vanish.[5]

7.3 Realized income taxation

Only a couple of years after the forest tax reform in 1991, the site productivity tax is to be replaced by a proportional realized income tax. According to the committee on capital income taxation (Pääomatulojen ... 1991) and subsequent more detailed suggestions (Puun myyntitulojen ... 1992), the uniform capital income tax rate will be extended to the realized income from forestry. (The sales tax will be applied to individual woodlots from 1993 with the owner's consent, or after a 13-year transition period). The proposals seem to be largely based on considerations other than economic efficiency, such as perceived administrational simplicity and, in the first place, apparent uniformity with the taxation of income from other assets. Nevertheless, the stated objectives also include a symmetric and thereby neutral tax system, and the realized income tax seems to be expected to meet this goal with respect to forestry.

Unfortunately, while the general outlines of the reform of capital income taxation seem reasonable, the forest tax proposal fails to correctly recognize its efficiency implications. With a uniform tax rate applied to interest income from other assets and realized income from forestry, net of management costs, the proposed tax system is equivalent to the case of the profit tax (π) under capital income taxation with $\pi = \tau$. As shown in section 5.3 of the present study, as well as by Kovenock (1986), such a taxation is not really neutral with respect to forest management decisions.

Given a uniform and constant tax rate on net timber revenue and other capital income (interest charge deductions), the budget constraints become $c_1 = (1 - \tau')(p_1H_1 - wE) - S$, $c_2 = (1 - \tau')p_2H_2 + [1 + r(1 - \tau)]S$ (even if $\tau = \tau'$, the tax levied on forestry income is "ear-marked" as τ' for exposition). The optimality conditions can be simplified to

$$(7.13a) \quad -p_2[1 + F_K(.)] + p_1[1 + r(1 - \tau)] = 0$$

$$(7.13b) \quad p_2F_E(.) - w[1 + r(1 - \tau)] = 0.$$

As all terms with $(1 - \tau')$ vanish, both the growing stock and other capital inputs in forestry are independent of the "forest tax rate" τ' but, since $1 + r(1 - \tau) < 1 + r$, higher than economic efficiency requires. In other words, a constant proportional profit tax as such is neutral with respect to both harvest timing and management intensity decisions, but inefficiencies arise from the taxation of the interest from other assets (interest charge deductions). Through a reduction in the opportunity cost of capital, the latter implies a delay in the realization time of timber (and encourages too low-yielding investments in forestry). Both intertemporal and intersectoral efficiency are violated and excess capital accumulates into forestry, as realized income taxation fails to recognize the capital gains aspect of an appreciating asset such as timber.

To illustrate the magnitude of the resulting management distortions, some numerical examples are provided (for details, see Appendix 9). Assume the nominal rate of interest is 10% and the annual rate of inflation is 6%, so that the undistorted real interest rate $r_u = r^* - \iota$ will be 4%. If a 25% tax rate is imposed on interest income from nonforest assets as well as interest charge deductions, the effective real interest rate $r_\tau = r^*(1 - \tau) - \iota$ will be reduced to 1.5%. (The figures are chosen to represent average or 'normal' conditions, assuming that on an average over time, private pre-tax real interest rates in well-developed capital markets tend to balance around the social discount rate. That is, the illustration abstracts from periods with exceptionally high nominal interest rates and/or low rates of inflation, during which the private after-tax interest rates may even exceed the social discount rate).

The impact of this change on the optimal harvesting decision can be illustrated (management intensity decisions are ignored here). Consider, first, the optimal growing stock using an aggregate size dependent growth function for Finland's forests (see Appendix 9). In this case, the long-run equilibrium stock at a reasonable 3–4% discount rate is about one third lower than at the 1.5% level. Secondly, it is illuminating to consider the management distortions at the stand level in terms of the optimal harvest age. As shown in Appendix 9, a reduction in the discount rate from 4 to 1.5% extends the optimal harvest age for common Finnish coniferous stands from 70–75 years to around 110 years.

The illustrative figures for the equilibrium stock must not be taken as a suggested policy goal (for example, the nontimber benefits of the forest justify a higher standing stock and longer rotation ages than otherwise). Due to stumpage price adjustments at the market level, the actual distortions would also be somewhat smaller that suggested above (see section 8.1. It depends on the industrial wood-using capacity whether, in fact, the equilibrium stock could ever be

reached). However, the examples suggest that the management distortions from a 25% capital income tax, equivalent to a reduction in the discount rate from 4% to 1.5%, may be far from insignificant. Appendix 9 also suggests that, assuming constant prices, the current growing stock (1880 mill. m^3) implies a marginal rate of return of less than 1%, which is very low compared to the social discount rate.

7.4 Conclusion

While evaluating the relative efficiency of the relevant forest tax alternatives for Finland, it should be noted that the income from other assets is taxed and interest charges for loans are tax deductible. Efficiency then requires that, rather than being neutral, forest taxation should in fact encourage timber harvesting so as to offset the delay in the realization time of timber caused by the capital income tax.

Realized income taxation, neutral at best, involves no such incentives and fails to achieve efficiency. Note that a "forestry deduction" (partial depreciation of the property's purchase price) is allowed in some cases. This – in fact, a feature of accrual income taxation – might encourage harvesting to some extent. However, the option only applies to forest properties acquired by purchase after the introduction of the new forest tax regime. Also, the unrealized capital gain from harvests below growth is not taken into account. On the other hand, the recent 1991 reform of the site productivity taxation made an attempt to encourage final fellings by more extensively exempting regeneration areas and seedling stands (thus, the forest's age structure is indirectly taken into account to some extent). Unfortunately, it is not completely clear whether such a harvest subsidy has the desired effect on harvest timing decisions when available on a permanent basis.

Because neither of the forest tax systems can be unambiguously shown to achieve efficiency, the efficiency effects of the switch from site productivity to realized income taxation remain open. Intuition suggests, however, that while timber harvesting may be temporarily encouraged during the transition period, the modified site productivity tax might have a merit over time.[6]

Given an income tax on nonforest assets, the value of the standing stock or unrealized increments therein should be taken into account if the tax system as a whole is to be neutral with respect to the realization of timber. In other words, economic efficiency calls for capital gains taxation. As shown in this study, and supporting Kovenock (1986), efficiency could be attained by either of the following forest tax schedules:

(1) An *ad valorem* property tax on the market value of the standing stock, at a rate equal to the interest rate multiplied by the capital income tax rate ($\alpha = r\,\tau$)[7]

(2) An accrual income tax on the realized harvest income plus the gain or reduction in the value of standing stock, at a rate equal to the capital income tax rate ($\kappa = \tau$).

That is, an income tax at the general capital income tax rate can be efficient if (but only if) the taxable income is defined on an *accrual* rather than realization basis.

Finally, note that alternative forest taxes have only been considered from the production efficiency point of view. Even if this is of fundamental importance (especially for economies heavily dependent on the forest-based sector such as Finland), other criteria have to be considered in practice for the choice of a forest tax base. These will be discussed in the following chapter.

Notes to Chapter 7

[1]A tax allowance for regeneration areas, first applied as a one-time deduction for the well-established seedling stand, was introduced in 1980. In the early 1980's, suggestions were made that the basic site productivity tax be weighted by the property's age class distribution (e.g. Riihinen 1982, Puuhuollon ... 1985).

[2]The constancy of ε is a simplification. With an increase in harvest, more hectares are exempted. Assuming a uniform site quality, the reduction in taxable income from an additional hectare is constant. If differences in the stocking per hectare are also ignored, the marginal increase in exempted land area per unit of timber cut is constant. That is, assuming $\varepsilon'(H_i) = \varepsilon_i > 0$, $\varepsilon'' = 0$ there is no need to consider whether ε is increasing or decreasing in the harvest, which depends on whether the most well-stocked or poorly stocked stands are cut first.

[3]As shown in Chapter 6, nontimber considerations would increase the optimal stock *ceteris paribus*. However, if there is no reason to subsidize or penalize the production of nontimber services through taxation, their inclusion would not change the main conclusions concerning the efficiency of forest taxes (see Table 1, Ch. 6). If private

forest owners tend to underproduce nontimber services, Chapter 6 suggests that the corrective tax rate under capital income taxation should be adjusted downwards for a larger standing stock.

[4]The 'socially optimal' management of forests is related to the social objectives that forestry is expected to achieve. As discussed earlier, (7.8) corresponds to the maximization of the present value of income (or utility of consumption) with given resources. This follows the standard approach in public economics. In practice, the society's objectives, or policy goals, may not be explicitly stated or there may be conflicting suggestions. (The derivation of a production goal for forestry from the goals of the national economy as a whole is discussed by Riihinen (1963, 1978) and Vehkamäki (1986), for example). In Finland, contradictory views concerning forest taxation's role in forest policy seem to be involved in recent decisions. The 1991 forest tax reform (Metsäverotoimikunta ... 1988, Laki maatilatalouden ...1990) was based on the view that forest taxation should encourage the use of forest resources. The 1991–92 tax proposals (Pääomatulojen ... 1991, Puun myyntitulojen ... 1992), in contrast, reject this view and consider neutral forest taxation to be desirable (see below).

[5]Assuming instead that a harvest subsidy is only available for a limited period (i.e., setting $x_2 = 0$ with only $x_1 > 0$), an appropriate combination of x_1 and δ could be found. It turns out that each can be solved independently from a single equation (both being necessary to restore efficiency with respect to both inputs). The solution

$$x_1 = pr\,\tau/[1 + r(1 - \tau)] > 0,$$
$$\delta = -r\,\tau/[1 + r(1 - \tau)] < 0$$

suggests that such a combination could be used as a *transitory* policy. The appropriate harvest subsidy x_1 is expectedly positive (while a negative management subsidy is more conventionally called a *payroll tax*).

[6]Some further aspects can be noted. First, collapsing the planning horizon into two periods may not be fully compatible with the actual exemption periods for regeneration areas. Suppose the current period is 5 years, while the exemption period is 15 years, for example. Then, the exemption due to the current harvest would in fact reduce the future tax as well, and the modified site productivity tax would be more likely to encourage harvesting. Secondly, taxes based on the actual harvest may invoke reactions that can not arise with taxes based on the potential harvest. If the forest owner possesses strong "tax aversions", there may be an incentive to delay the realization of timber in order to minimize, or defer, one's tax payments.

[7]Given $\tau = 0.25$ and $r^* = 0.10$, exactly restoring the undistorted realization time would require a property tax at 2.5% ($\alpha = r^* \tau = 0.10 \times 0.25$). In practice, property tax rates are bound to be lower. The "fully corrective" rates would imply excessively high tax burdens; computationally, a 2.5% annual tax on the market value of the stock would be equivalent to a 50% income tax, if the annual yield is 5% of property value. Also, the tax rate might have to be adjusted downwards to allow for the stock dependent scenic and recreational services. Following the same example, a 1.25% property tax would correspond to a 25% income tax.

8 Tax incidence, equity, and administrational aspects

This chapter considers criteria other than production efficiency that are of importance in the choice of a "good" forest tax base. Of greatest importance are the horizontal and vertical equity and administrational issues (The Structure ... 1978, Boadway &Wildasin 1984, Rosen 1985, Auerbach 1985, Slemrod 1990). Even if the points to be made on the equity issue – or on tax incidence – are well-known to readers familiar with the basic ideas of public economics, they have not been crystal clear in the forest tax debate. Further, administrational aspects can be essential to the policy implications of any tax results (e.g. Slemrod 1990). Even if no final answers will be provided, administrational issues are therefore discussed in order to outline problems that need to be examined in more detail.

Section 8.1 considers the incidence of forest taxes, i.e. their effects on stumpage prices and income distribution between forest owners and timber users. The horizontal and vertical equity between forest owners is discussed in section 8.2. It should be noted that any evaluation of equity is based on value judgments concerning the "fair" distribution of the tax burden, and a reasonable argument requires that the judgments are made explicit. The following discussion is based on what is usually meant by equitable taxation in public economics. Finally, the administrational feasibility and costs of the main tax alternatives are discussed in section 8.3.

8.1 The incidence of forest taxes

So far, the center of attention has been the individual forest owner facing given stumpage prices. In this section, a downward sloping rather than horizontal demand schedule will be assumed to give an idea of the market level effects of taxation on stumpage prices and income distribution between the forest owners and timber users. Such issues are referred to by the term *tax incidence*. The discussion is based on the effects of the lump-sum, yield and *ad valorem* property taxes without nontimber considerations in Chapter 5. (For distributional effects, the point of reference is the *status quo* irrespective of whether the initial equilibrium is undistorted or one distorted by capital income taxation).

The *economic incidence* of a tax (to whom the tax burden ultimately accrues) must be distinguished from its *statutory incidence* (who is legally responsible for paying the tax). The two will generally not coincide (Auerbach 1985, Rosen 1985). If forest taxes, for example, affect individual forest owners' harvesting decisions, they give rise to shifts in the aggregate supply of timber. Given that the stumpage price is determined by the interplay of supply and demand[1], such shifts in turn affect the market price and income distribution between timber buyers and sellers via tax shifting. To which party the tax will mainly accrue depends on the relative steepness of the demand and supply curves. In what follows, the extreme cases of perfectly elastic or inelastic demand/supply curves are ruled out and the ordinary case with a downward sloping demand and upward sloping supply curve is considered.

The demand for timber is derived demand, which can be modelled as the maximization of the firm's profits with respect to the use of roundwood and other inputs.[2] In the short run, the capital input is fixed, so the problem is adjusting the utilization rate of a given production capacity. Because adjustment incurs cost and factor substitution is limited in the short term, the short-run demand tends to be relatively inelastic. In the long run, the capital input is also variable. The problem then is to choose the optimal capacity itself. Thus, long-run demand is determined by the level of investment in the forest industries and technical change. With additional choice variables and possibilities for factor substitution, the long-run demand is likely to be more price elastic.[3]

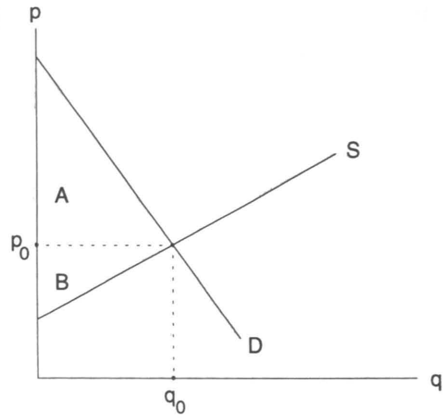

Fig. 3. Buyers' and sellers' surpluses (A and B), with equilibrium price p_0 and quantity traded q_0.

Lump-sum taxes

Suppose an allocatively neutral tax, such as the unmodified site productivity tax, is initially used. Given supply and demand curves S and D, the volume traded and stumpage price in the timber market are q_0 and p_0 (Fig. 3). The buyers' and sellers' surpluses are the triangles A and B, respectively. As the timber supply is unaffected by the lump-sum tax both in the short and long run, there is no tax shifting and the statutory and economic incidences coincide (in the long run, this also applies to the profit tax). Next, suppose the lump-sum tax is replaced by a nonneutral tax with the tax rate set so as to raise an equal tax revenue.

Yield taxes

Consider the short-run effects (stage (2) in section 5.2.2) of a switch to the gross yield tax (the same broadly applies to the profit tax). The initial supply curve S^0 in Fig. 4(a) indicates that for the sellers to supply a given quantity of timber, they must receive the price p per unit. Given a yield tax at rate γ, the sellers receive $(1 - \gamma)p$ for timber sold at the price of p; for them to receive the same unit price after the tax, timber users would have to pay $p/(1 - \gamma) \approx (1 + \gamma)p$. That is, the supply curve perceived by the users after the tax will be S^1.[4] The quantity traded at the new equilibrium is q_1, the price

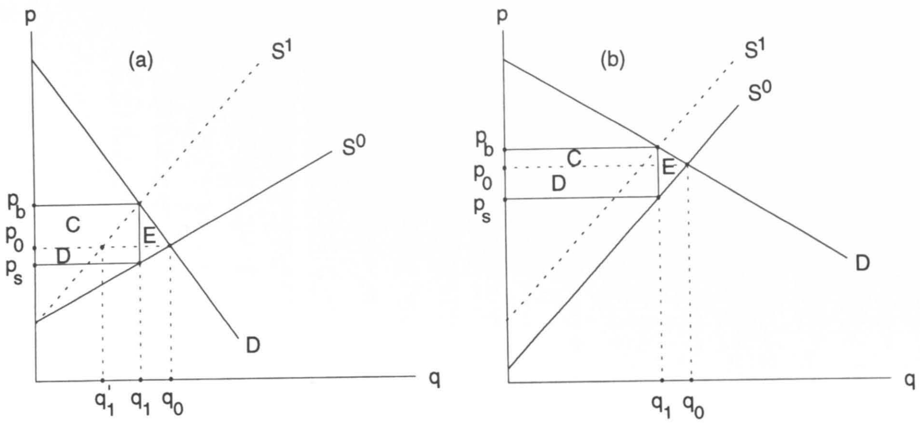

Fig. 4. The excess burden (E) and incidence of taxes between timber suppliers (D) and timber users (C). (a) The yield tax in the short run. (b) The yield or property tax in the long run.

paid by the buyers is p_b, and the after-tax price received by the sellers is p_s.

Owing to the price adjustment, the quantity traded is reduced by less than it would with a fixed stumpage price (to q_1 rather than q'_1). The total amount collected as tax revenue is the area C + D, with the tax ultimately accruing to the timber suppliers represented by rectangle D and the tax accruing to the buyers denoted by C. Timber users therefore lose compared to the lump-sum tax, because part of the tax burden shifts to them via higher stumpage prices. (As the total reduction in surplus, C + D + E, is greater than the total tax revenue C + D, the reduction in output generates an excess burden denoted E). In the long run, the gross yield tax (given $h_\gamma < 0$) shifts the aggregate supply schedule to position S^1 in Fig. 4(b). Part C of the tax shifts to the timber users as a result of the higher price p_b.

Ad valorem property tax

The short-run analysis of the *ad valorem* property tax is the reverse of the yield tax. The *ad valorem* property tax at rate α appears as an increase in the after-tax stumpage price received by the seller, i.e. his/her perceived price becomes $(1 + \alpha)$p per unit. For the seller to get p after the tax, the buyers need to pay $p/(1 + \alpha) \approx p(1 - \alpha)$, so the supply curve perceived by the buyers becomes S^1 (Fig. 5). The stumpage price they pay is p_b while the sellers' perceived price is p_s. Timber buyers benefit as compared to lump-sum taxation through lower stumpage prices so that their surplus increases by the area H + I. The sellers' surplus also increases by F + G (cf. the effects of a subsidy, Auerbach 1985), which represents the property tax that the forest owners escape by increasing the current harvest.

The net outcome from the sellers' point of view depends on exactly how the tax rate is set. If α is not fully adjusted in advance for the increase in harvest, the actual revenue from property taxes will fall short of T^0 originally collected by the lump-sum tax. The sellers, on net, are then left better off in the short run. If α is fully adjusted to collect exactly T^0 despite the reduction in taxable stock, the tax will exhaust the increase in sellers' surplus and the forest owners are left as well off as before. (An excess burden E is generated, however, because the units of timber between q_0 and q_1 are valued at less than their true social opportunity cost). For the steady state implications of the *ad valorem* property tax, Fig. 4(b) applies (timber users pay part of the tax via higher stumpage prices).

The following conclusions can be made. In the short run, replacing a neutral forest tax by a *yield tax* with the same total revenue would make timber suppliers better off via tax shifting. However, this is at the cost of making timber buyers worse off, so the switch cannot be Pareto optimal from the two parties' point of view. Substituting an *ad valorem property tax* for lump-sum taxation would make the buyers better off and leave the sellers at least as well off in the short run. In the long run, both yield and *ad valorem* property taxes, while leaving the sellers better off, would make timber users worse off. The switch therefore is not Pareto efficient for the parties.

Finally, a general implication of the incidence analysis is that the adjustment of stumpage prices at the market level reduces the magnitude of tax-induced management distortions (cf. Gamponia & Mendelsohn 1987). The qualitative conclusions concerning the efficiency of taxes will not change, but the overall management distortions from capital income taxation will be quantitatively smaller than those suggested in section 7.3, based on the representative forest owner's case.

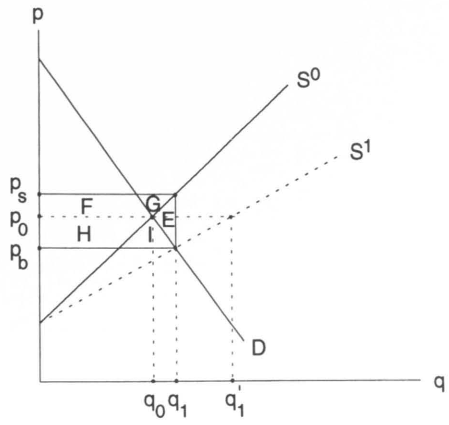

Fig. 5. The excess burden and distributional effects of the *ad valorem* property tax in the short run.

8.2 Equity issues

This section considers the equitable distribution of the tax burden between forest owners. *Horizontal equity* implies that individuals who are in equal positions should be treated equally. In other words, people who are equally well off should bear equal tax burdens. *Vertical equity* has to do with how taxation treats individuals at differing levels of welfare; a person with greater taxable capacity should bear the greater tax burden (e.g. The Structure … 1978, Boadway & Wildasin 1984).

In what follows, vertical equity is defined in the weak sense that the tax burden should be *proportional* to the individual's taxable capacity. While the vertical equity has often been associated with the redistribution of income through progressive income taxation, the idea has recently lost much of its popularity. With more attention being paid to the disincentive effects of progressive taxes, the trend in capital income taxation is towards proportional taxes (accordingly, progressive forest taxation has been ignored throughout the study).

A fundamental question is the proper definition of an individual's taxable capacity or ability to pay. The view adopted here is that an equal taxable capacity should be judged by the similarity of *opportunity* rather than similarity of outcomes, which depend on the individuals' own decisions (see The Structure … 1978, Rosen 1985). In terms of the income concept, this is consistent with the Haig-Simons comprehensive definition (see e.g. Boadway &Wildasin 1984, Musgrave 1985). A person's income is the money value of net accretion to his/her "economic power"; more specifically, it is the value of what he/she could consume during a year (A) without diminishing his/her capital, or (B) while being left with opportunities to maintain the same level of consumption indefinitely in the future (The Structure ... 1978). In other words, income can be defined as the sum of current consumption plus capital gain or loss.

8.2.1 Horizontal and vertical equity

As applied to forestry, the above view implies that whether two forest owners should bear an equal tax burden or whether one of them should bear a greater tax should be judged by their *harvest potential* and changes therein, rather than realized income. In other words, an equitable forest taxation should take into account the individual forest property's *income-earning capacity* as reflected in the woodlot's harvest potential. The tax burden would accordingly increase in proportion to the owner's *forest-related* wealth and ability to pay (while tax progression and the owner's overall wealth are omitted). As regards the correct income concept for forestry, this leads to the comprehensive concept of accrual income, which defines a period's income as the realized income plus any change in the value of standing stock. Naturally enough, equity, in the sense defined above, would be met by an accrual income tax. Consider next its common substitutes.

Site productivity taxation

Conceptually, the site productivity tax is consistent with definition B of the comprehensive income above (the mean annual value increment representing the accrual income as an average). However, annual site productivity taxes are frequently criticized because taxes are paid continuously while cash income is only obtained at harvest time. On properties that are previously heavily cut, the computational average income may then overestimate the actual harvest potential in the short term, or even for an individual owner's life-time. Generally, this applies where the owner's forest-related wealth mainly consists of immature stands (in Finland, for example, final cutting is not allowed below a specified minimum age). On the other hand, taxable income will be underestimated on properties with high initial endowments of mature timber. This is a potential problem with the unmodified site productivity tax, where an equal tax rate is levied on all age classes. In the modified site productivity taxation in Finland (since the 1980 and 1991 reforms), these problems are alleviated by implicitly recognizing the age distribution via tax exemptions on regeneration areas and seedling stands.

Realized income taxes

It is sometimes suggested that the problem of taking the individual woodlot's harvest potential into account would be resolved by realized income taxation. Indeed, it eliminates the possibility of taxes being levied for assumed income that never was or could not be realized. In fact, however, realized income taxation involves several drawbacks with respect to horizontal as well as vertical equity. The basic reason is that the concept of realized income fails to consider the woodlot's harvest *potential* at all. Thus, of two woodlots with an equal initial harvest potential (income-earning capacity), one may be cut and thereby taxed heavily while the other may be completely exempted if the owner abstains from cutting. As for vertical equity, the tax burden is by no means proportional to the initial or remaining forest-related wealth.[5]

On the other hand, realized income taxation fails to recognize the capital gains aspect. The concept of realized income is consistent with the comprehensive definition only if the annual cut remains close to the annual timber growth. If the harvest significantly exceeds the relevant period's growth, the remaining timber inventory or forest-related wealth declines. Taxing the entire realized income, including the harvest in excess of growth, therefore implies taxing what represents a transformation of one's capital into another asset rather than real income. If the harvest is less than growth (or zero), the unrealized accumulation of the standing stock remains untaxed, even if it represents an increase in the owner's wealth. (Of course, the uncertainties involved in the growth function and future timber prices must be held in mind while estimating the capital gain).

Ad valorem property tax

Based on the potential harvest value of the standing stock, the tax burden under *ad valorem* property taxation is proportional to the woodlot's harvest potential and thereby the owner's forest-related wealth. Given that the mature timber is a liquid asset, the latter also reflects the forest owner's ability to pay. Note that the *ad valorem* property tax is defined as a tax on the market value of the standing stock; thus, if properly applied, juvenile stands with no or little merchantable timber are tax exempted by definition or only lightly taxed. Even if simplified tax schedules need to be used in practice (see section 8.3), the *ad valorem* property tax seems to outperform both site productivity and realized income taxes in terms of horizontal and vertical equity.

8.2.2 Realization possibilities for timber

The argument that annual site productivity or property taxes on the forest are "unfair" seems analogical with the fear that, more generally, taxing capital gains on accrual rather than realization might force the owners to sell assets prematurely to raise revenue for the taxes (e.g. Boadway & Wildasin 1984). In the case of forestry, however, such liquidity problems, with related premature harvesting, are in most cases unlikely to be a real issue. As age classes usually coexist, cash income can be received more or less regularly.[6] Problems may appear – i.e., the computational value increment or taxable property value may overestimate the forest owners' real income-earning capacity in the aggregate – if there is no demand for all the timber grown. The potential for such a problem exists in Finland, for example, where the annual timber growth exceeds the foreseeable wood-using capacity and the demand may be limited for stands with less favorable locations and lower-grade timber assortments.

With realized income taxation, based on actual transactions, the unit value of the timber and potential limitations to its realization possibilities are automatically correctly recorded. Thus, the realized income tax can flexibly adjust to changes in the demand situation and stumpage prices. The annual taxes based on the potential income or harvest value require special adjustments to allow for a potential excess supply. While not without difficulty, the problems should not be overstated. (In Finland's forest taxation, for example, a "safety margin" has been applied to guarantee that no one is taxed too heavily. Since 1991, the determination of taxable income was further adjusted to allow for the pervasive excess of aggregate timber growth over the annual harvest levels).

8.3 Administrational simplicity and costs

Most literature on optimal taxation has implicitly assumed that collecting taxes is costless. So far, the present study has similarly ignored the administrational feasibility and costs of forest taxes. However, the total cost of collecting tax revenue is in fact the sum of the excess burden and administrational costs (Rosen 1985, p. 321–322). As alternative tax systems may differ in the cost of their application, as emphasized by Slemrod (1990), administrational simplicity and costs are relevant additional criteria for the choice of a tax base. While providing gains in terms of production efficiency, implementing a more sophisticated tax system is likely to call for a larger administration and incur greater costs. While any detailed analysis of the forest tax administration is beyond the scope of this study, some general notes will be made below. In the first place, the administrational simplicity and costs of alternative forest tax regimes have to do with their informational requirements, i.e. the gathering and updating of data for implementation.

Technical and administrational simplicity is frequently considered to be a major advantage of *realized income taxation.* For a realized income tax with immediate expensing and no individually based management cost deductions (the gross yield tax in the present study), this is undoubtedly true. Collecting a fixed per cent of tax on the gross sales revenue at source, no site type classifications, records of tax exemptions, or verification of management costs would be needed. However, it is not that simple if actual management costs are taken into account on an individual basis, as recently suggested in Finland (the profit tax in the present study). Resource costs are incurred because the silvicultural costs must be verified and recorded by the authorities to determine the final tax liability.

For *site productivity taxation*, a comprehensive classification of forest lands is required to estimate the annual taxable income (mean annual value increment) by site type. Establishing and periodically updating such a data base incurs a significant cost. In the unmodified form, however, this is about all, since a schematic deduction for the average management costs will suffice. The modified site productivity tax in Finland involves a number of complications (exemptions for regeneration areas and seedling stands, individually based deductions for reforestation and brush control, etc.), which incur additional administrational work.

The *ad valorem property tax*, literally, is a tax levied on the market value of the standing stock. Its application calls for a reasonably up-to-date record of the age class distribution of individual woodlots. The dominant tree species and site productivity also need to be known stand by stand in order to estimate the commercial value of the stock and its growth rate. In practice, simplified schedules should be used. In Finland, where a site type classification exists, a suggestion has been made that the "flat" site productivity tax could be weighted by stand age. That is, the per hectare tax burden would be determined by the development stage of the stand (Riihinen 1982, Puuhuollon ... 1985) or by e.g. three broad classes of stand age. (In fact, this would amount to having forest management plans maintained for tax purposes. According to Leikas (1990), mandatory forest management plans are used to determine the woodlot's sustainable harvest in the forest taxation in Germany and Austria). In any case, the informational requirements and costs exceed those for the site productivity tax.

Two concluding remarks on the evaluation of the relative administrational merits of forest taxes should be made. First, for a relevant comparison between the realized income vs. site productivity taxes, it seems decisive which specific applications are compared, and whether a site type classification initially exists. Where such a classification does not previously exist, especially the simplest types of realized income taxation obviously outperform site productivity taxation in terms of operational costs. However, where a site type classification exists, this is not clear. Especially an unmodified site productivity tax, with few or no adjustments, might well be competitive with the more sophisticated types of realized income tax (the profit tax).

Secondly, the gains in administrational costs attainable by a simpler tax system must be weighted against the efficiency gains that a more sophisticated tax system might provide. In the present context, efficiency gains could be achieved by choosing forest taxes so as to offset the management distortions from capital income taxation. Now, if the operation costs of the profit tax and site productivity taxation do not differ significantly, the qualitative conclusions on their relative efficiency (see the summary in section 6.5) will not change even if costs are taken into account.

The *ad valorem* property tax makes a difference due to significantly higher resource costs. Therefore, even if the management distortions from capital income taxation are significant, it is not *a priori* clear whether it is pays to try and eliminate them through a more resource-consuming forest tax system. (Neither can this be ruled out *a priori*. Collecting sufficiently accurate data on individual properties is becoming technically feasible, at least, with recent developments in remote sensing techniques). To evaluate the net gains, a computable general equilibrium model is required to estimate the economy-wide effects and attainable benefits of removing the tax-induced lock-in effect on the realization of timber. For an outline for such an analysis, one may refer to Boyd & Daniels (1985) or Boyd & Hyde (1989).

Notes to Chapter 8

[1]The assumption means that stumpage prices adjust to changes in supply and demand so that the timber market equilibrates every period. Price adjustment may be hindered or rendered sluggish by agreements on recommended prices between the sellers' and buyers' organizations (e.g. Finland, Sweden). While no decisive evidence exists (see Kuuluvainen *et al.* 1988), downward price rigidity may be generated by such arrangements.

[2]Following Johansson & Löfgren (1985), a competitive firm's short-run timber demand can be modelled as the maximization of the profit function $\prod = Pf(c,l) - pc - wl$, where $y = f(c,l)$ is the firm's production as a function of roundwood and labor inputs c and l, respectively, P is the price of end products, and p and w are stumpage price and unit wage. The demand function will be the solution with respect to c. In the long run, the capital stock and the level of technology are also variable, and the production function can then be written as $y = f(K,c,l;T)$, where K is the capital input and T denotes the (exogenous) level or change of technology (e.g. Hetemäki 1990, Hetemäki & Kuuluvainen 1991).

[3]In contrast, timber supply can be taken to be more price elastic in the short than in the long run (Chapter 3 and Appendix 1). Typically, then, the short-run case can be characterized by a relatively elastic supply and inelastic demand, while in the long run the opposite is true as far as theory is concerned. For empirical evidence on short-run timber supply and demand, see Brännlund *et al.* (1985), Kuuluvainen (1985, 1986), Tervo (1986), Newman (1987), Kuuluvainen *et al.* (1988), Aronsson (1990a), and Hetemäki & Kuuluvainen (1991). For long-run timber supply, no empirical evidence is readily available. However, several studies on the short-term supply (Brännlund *et al.* 1985, Kuuluvainen *et al.* 1988, Hetemäki & Kuuluvainen 1991) have included the previous period's price, representing expected future price, and reported negative elasticities with absolute values close to those for the current price. This suggests that the total "medium-term" or "long-term" price elasticity is close to zero.

[4]It is implicit here (cf. section 5.2.2) that immediately after the new regime has been imposed, the sellers only perceive the current tax. Due to a stock effect, however, the supply schedule will shift to the left at stage (2) irrespective of this assumption. Thus, even if the supply schedule shifted with its slope unchanged, the qualitative results would be the same.

[5]Even more, the tax burden may be inversely related to the forest owner's ability to pay. A forest owner with high enough overall wealth to abstain from cutting may completely escape the tax, while a low-income forest owner who depends on the timber revenue is taxed for the entire realized income.

[6]Owner-occupied housing is a perfect example of illiquid wealth with no cash receipts at all (therefore, its imputed income is rarely taxed). For assets which do produce cash income, liquidity problems do not appear if there are well-developed capital markets with no major constraints on borrowing against future income.

9 Summary and conclusions

The final chapter summarizes the main theoretical results and policy implications of the study. The results on the effects and relative efficiency of common forest taxes (Chapters 4, 5, and 6) are first discussed chapter by chapter, as well as the more specific forest tax issues in Finland (Chapter 7). Besides production efficiency, the additional aspects of equity and administrational costs (Chapter 8) are finally incorporated for an overall evaluation of alternative forest taxes.

The model

After a review of earlier forest tax literature (Chapter 2), the analytic tool for the study was developed in Chapter 3. The now frequently used two-period model of consumption and timber harvesting was extended by incorporating the management intensity decision. In addition to short-run timber supply, the generalized model can be used to analyze the long-run steady state timber supply and proves to be a discrete time counterpart of the well-examined models for renewable resources.

The effects of common forest taxes

In the positive analysis of forest taxes in Chapter 4, as well as Chapter 5, only the income from timber production was assumed to matter. Perfect capital markets and perfect foresights were assumed to exclude income effects which are irrelevant from the efficiency point of view. Under these assumptions, lump-sum taxes, such as the unmodified site productivity tax, are neutral with respect to short-run supply, management intensity and long-run timber supply. For the realized income (yield) taxes, the temporal variations in the tax rate matter. However, the profit tax, with full deductions for costs, is neutral if the tax rate is perceived to be constant over time. The *ad valorem* property tax unambiguously encourages timber harvesting. The impacts on management intensity and long-run supply are respectively ambiguous or negative. As noted in Appendix 1, the results for the stationary case are rather similar to those which could be indirectly concluded from the rotation model (the timing effects cannot be considered in the latter).

The relative efficiency of forest taxes

As the core of the study, Chapter 5 considered the *normative* question of the appropriateness of alternative forest tax regimes from the standpoint of production efficiency. The conclusions differ from the suggestions made (frequently based on implicit arguments only) in most of the earlier forest tax literature. This is because, with the notable exception of Kovenock & Rothschild (1983) and Kovenock (1986), earlier discussions have explicitly or implicitly assumed an initially undistorted, untaxed economy or failed to consider the tax system as a whole. In that case neutral forest taxes, such as the site productivity or profit tax, do appear desirable. Criticism of the nonneutrality of *ad valorem* property taxes would also be justified.

Following Kovenock & Rothschild (1983), Kovenock (1986) and Chisholm (1975), the present study adopts a different view. Noting that the assumption of no pre-existing taxes and tax distortions is unlikely to approximate any real economy, the policy implications based on such an assumption tend to be misleading. Once the effects of a capital income tax levied on other assets (interest charge deductions) are recognized, neutral forest taxes may no longer be desirable. Rather, the two in combination induce a lock-in effect on the realization of timber. As a nonneutral forest tax need not imply social undesirability, the adverse effects of the capital gains taxation of forests seem ill-argued (for reviews of the U.S. forest tax debate, see Klemperer 1977, Boyd 1986). Rather than forcing forest owners to cut prematurely, a properly set *ad valorem* property tax might just restore efficiency by offsetting the lock-in effect from the tax-induced reduction in the opportunity cost of capital. Efficiency can be met by an income tax if (but only if) levied on an accrual rather than realization basis.

The role of nontimber benefits

To see whether the tax conclusions are sensitive to the assumptions concerning the forest owner's and/or policy-maker's objectives, the imputed utility from the forest's nontimber services was incorporated in Chapter 6. Due to income effects, even lump-sum taxes prove to be nonneutral, and the stable profit tax is no longer without substitution effects. The efficiency criterion now involves the marginal valuation of the standing stock as it represents the production of amenities. However, the main conclusions on the relative efficiency of forest taxes are rather robust (see section 6.5 for a summary).

If there is no need to subsidize or discourage the production of amenity services through taxation, lump-sum taxes are efficient in the absence of pre-existing tax distortions. Given the capital income tax, the *ad valorem* property tax is optimal with exactly the same rate as without nontimber considerations. Where the private forest owners tend to underproduce nontimber services, the property tax rate in the latter case should be adjusted downwards for a greater standing stock. Notably, realized income taxation – as far as the profit tax is concerned, at least – does not appear to be an appropriate way to allow for the production of external benefits. For reasons discussed in Chapter 6, this conclusion contrasts with earlier suggestions (e.g. Heaps & Helliwell 1985, Gamponia & Mendelsohn 1987).

Forest taxation in Finland

Chapter 7 considered both the modified site productivity taxation applied in Finland and the realized income tax, which is to replace the previous system. Given a capital income tax on other assets, the appropriate forest tax should take into account the harvest potential and/or changes therein, if taxation as a whole is to be neutral with respect to forest management decisions. (That is, efficiency calls for the capital gains taxation of forestry).

The recent forest tax reform made an attempt to encourage the realization of timber by more extensively exempting regeneration areas and seedling/sapling stands. Unfortunately, it is not completely clear whether the harvest subsidy has the desired effect on harvest timing decisions when available on a permanent basis. On the other hand, realized income taxation is to be introduced by extending the uniform capital income tax rate to the net realized income from forestry. Based on considerations such as apparent uniformity with the taxation of other assets and perceived administrational simplicity, the proposal fails to recognize the overall effects on the realization of timber. While neutral as such, the realized income tax thus implies efficiency losses over time (illustrative examples are given in Appendix 9).

An outline for overall evaluation

In Chapters 5 through 7, forest taxes were considered from the efficiency point of view. However, other criteria matter in the choice of a forest tax base. Both horizontal and vertical equity were considered in Chapter 8, based on the view that an equitable forest tax should take into account (be proportional to) the property's income-earning capacity as reflected by the harvest potential. General notes were also made concerning the informational needs and related administrative costs of the tax alternatives. A brief outline for an overall evaluation of the common forest taxes, considering both production efficiency, equity and administrational aspects, can be given as follows.

(1) The *unmodified* site productivity tax is consistent with production efficiency only in the absence of any previous tax distortions. Equitable in the long run, but not necessarily in the short term, it incurs significant administrational costs via site type classification. Due to the exemption for seedling stands, the *modified* site productivity taxation (e.g. Finland) is more consistent with production efficiency in the presence of capital income taxation, as well as equity, but incurs additional operation costs.

(2) Realized income taxation is inconsistent with production efficiency, especially where income from nonforest assets is taxed, and it involves inconsistencies with horizontal and vertical equity. Obvious administrative gains are provided by versions with no individually based deductions, but these are likely to be lost if cost deductions are recorded in detail.

(3) A properly set *ad valorem* property tax is consistent with production efficiency under capital income taxation and outperfoms both site productivity and realized income taxes in terms of equity, but it incurs significantly higher administrative costs. A computable general equilibrium model is required to estimate the attainable economy-wide efficiency gains and compare them with the additional cost of operation.

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Seloste

Metsäverotus, puun tarjonta ja taloudellinen tehokkuus

Johdanto

Eri maissa käytetyt metsäverojärjestelmät voidaan luokitella kolmeen päätyyppiin. Metsäverotus perustuu joko kasvupaikan tuottokykyyn eli keskimääräiseen tuloon (pinta-alaverotus), realisoituun tuloon eli aktuaalisiin puunmyyntituloihin (myyntiverotus) tai metsäomaisuuden – ennen kaikkea puuvarannon – markkina-arvoon (*ad valorem* -omaisuusverot). Varhaisessa tutkimuksessa metsäveroja vertailtiin käyttäen mm. site burden -mittaa, jolla tarkoitetaan verojen suhteellista vaikutusta maan arvoon. Myöhemmän tutkimuksen tärkeimpiä ongelmia on ollut metsäverotuksen vaikutus optimaaliseen kiertoaikaan ja metsänhoitoinvestointeihin. Perustulosten mukaan pinta-alaverotus on neutraali, kun taas myyntiverot tyypillisesti vaikuttavat kiertoaikoja pidentävästi ja puuston arvoon perustuva omaisuusvero kiertoaikoja lyhentävästi.

Vaikka metsäverotuksen vaikutukset sinänsä tunnetaan suhteellisen hyvin, vaihtoehtoisten metsäverojen *taloudellista tehokkuutta* koskevat päätelmät ovat olleet näkökulmaltaan ja pätevyydeltään rajoittuneita. Ensiksikin site burden -käsite ei kuvaa oikein suhteellista tehokkuutta. Kun metsän käsittely on oletettu verotuksesta riippumattomaksi, mitta on yksinkertaisesti sama kuin veron nykyarvo. Teoreettisesti oikea tehokkuuskriteeri on verotuksen tehokkuusrasitus (excess burden), jossa otetaan huomioon verotuksen aiheuttamista käsittelypäätösten vinoutumista seuraava tulojen menetys. Käsite tuli metsäverokirjallisuuteen yllättävän myöhään. Toiseksi tavoiteltavasta metsäverotuksesta keskusteltaessa on – eräitä merkittäviä poikkeuksia lukuun ottamatta – oletettu, että taloudessa ei ennestään ole metsänomistajien päätöksiin vaikuttavia veroja tms. vinouttavia tekijöitä. Jos lähtötilanne näin vastaa voimavarojen tehokasta kohdentumista, neutraali metsäverotus on luonnollisesti haluttava. Neutraalisuus on kuitenkin tarkoituksenmukainen tavoite vain siinä tapauksessa, että se määritellään ottaen huomioon verojärjestelmän kokonaisuus. Jos taloudessa on ennestään metsätaloudellisia päätöksiä vinouttavia veroja, tulisi näiden ja metsäverojen vaikutuksia tarkastella yhtä aikaa. Ei-neutraali metsäverotus voi tällöin osoittautua taloudellisesti tehokkaammaksi. Tärkeä esimerkki metsänomistajan päätöksiin vaikuttavista muista kuin metsäveroista on korkotulojen verotus (korkomenojen vähennettävyys), joka alentaa pääoman yksityistä vaihtoehtoiskustannusta.

Samat kysymykset, jotka ovat olleet keskeisiä teoreettisessa kirjallisuudessa, ovat olleet esillä myös Suomen metsäveropolitiikkaa koskevassa keskustelussa. Keskustelun ongelmana on ollut selkeän käsityksen puuttuminen vaihtoehtojen allokatiivisista vaikutuksista. Esim. vuonna 1991 uusia verokannustimia käyttöön otettaessa niiden vaikutuksia ei osoitettu tutkimuksin. Toisaalta puun myyntitulojen verotukseen siirtymistä koskevat ehdotukset näyttävät kokonaan sivuuttavan tehokkuusnäkökohdat.

Tutkimuksen tarkoitus

Tutkimuksen keskeinen ongelma on eri metsäverojärjestelmien suhteellinen tehokkuus (efficiency). Käsiteltävät päätyypit ovat pinta-alaverotus, myyntiverotus sekä *ad valorem* -omaisuusvero. Lisäksi tarkastellaan kertymäpohjaisen tulon (realisoitu tulo + omaisuuden arvon muutos) verotusta, joka osoittautuu tehokkuusominaisuuksiltaan em. omaisuusveroa vastaavaksi.

Tehokkuuskriteeri liittyy verotuksen allokatiivisiin vaikutuksiin. Perusajatus on, että verotulojen keruun tulisi vinouttaa taloudellisia päätöksiä mahdollisimman vähän. Toisin sanoen verotuksen tehokkuusrasituksen kullakin annetulla verokertymän tasolla tulisi pysyä mahdollisimman pienenä. Tehokkuusrasituksella tarkoitetaan verotuottona kerätyn määrän ylittävää tulojen tai hyvinvoinnin menetystä.

Metsätaloudessa keskeiset voimavarojen kohdentumisen ongelmat koskevat investointeja puustopääomaan sekä metsänhoitoon. Tehokas allokaatio merkitsee, että puustopääoman ja muiden panosten rajatuotot ovat yhtä suuret kuin pääoman kansantaloudellinen vaihtoehtoiskustannus (pääoman tuottoaste talouden muissa sektoreissa). Ongelman käytännöllinen merkitys lienee intuitiivisesti selvä: metsänomistajien puustopääoman pitotai hakkuupäätökset määräävät raakapuun lyhyen aikavälin tarjonnan, kun taas puustopääoma ja metsänhoidon taso määräävät puuston kasvun eli pitkän aikavälin potentiaalisen tarjonnan. Jos verotus esim. heikentää puun tarjontaa, seurauksena on lyhyellä aikavälillä tuotantomahdollisuuksien tuhlaus. Vaikka suurempi puuvaranto merkitsisi suurempia kestäviä hakkuumahdollisuuksia, pääomien kohdentuminen muodostuu tehottomaksi, koska metsätalouteen sitoutuu liikaa pääomaa verrattuna talouden muihin sektoreihin.

Tutkimuksen tavoitteet ja pääsisältö ovat seuraavat.

(1) Aluksi kehitetään analyysiin soveltuva puun tarjonnan teoreettinen malli. Fisherin kulutus-säästämismalliin perustuvaa kahden periodin mallia laajenne-

taan siten, että lyhyen aikavälin tarjontapäätösten lisäksi voidaan tarkastella metsänhoitoinvestointeja ja pitkän aikavälin tarjontaa.

(2) Mallin avulla tutkitaan pinta-alaverotuksen, myyntiverojen ja *ad valorem* -omaisuusveron vaikutuksia metsänomistajan hakkuu- ja investointipäätöksiin. Erona aikaisempaan kirjallisuuteen on, että työssä tarkastellaan suoraan verojen vaikutuksia puun tarjontaan (ei kiertoaikaan) ja lisäksi sekä lyhyen että pitkän aikavälin vaikutuksia.

(3) Tutkimuksen keskeinen tehtävä on määrittää taloudellisen tehokkuuden kannalta haluttava metsäverotuksen rakenne. Tässä erotetaan kaksi tapausta. Ensiksi oletetaan lähtötilanteen edustavan tehokasta pääomien kohdentumista. Toiseksi oletetaan, että metsänomistajan päätöksiin vaikuttaa ennestään muiden pääomatulojen verotus (korkovähennysoikeus). Verotustulosten herkkyyttä tavoitefunktion suhteen tutkitaan ottamalla huomioon metsän maisema- ja virkistysarvot.

(4) Suomen metsäverotusta käsitellään erikseen ottaen huomioon korkotulojen ja -menojen verokohtelu. Toisaalta tarkastellaan pinta-alaverotusta v. 1991 jälkeisessä muodossaan, toisaalta myyntiverotusta, johon on tarkoitus siirtyä v. 1993 alkaen.

Muiden pääomatulojen verotusta käsitellään annettuna, kuten on realistista. Näin ollen tehokasta metsäverotusta koskevat tulokset edustavat osittaisratkaisua metsätalouden tuotannollisen tehokkuuden kannalta. Pääomatuloverotuksen vaikutukset erityisesti hakkuupäätöksiin tulevat siis korjatuiksi, mutta sen kulutus-säästämispäätöksiä vinouttavat vaikutukset säilyvät.

Teoreettinen malli

Työ on tutkimusotteeltaan teoreettinen. Tämä on luonteva valinta, kun tutkimuksen keskeinen kohde on verojärjestelmien suhteellinen tehokkuus. Tästä näkökulmasta merkitystä on vain verojen substituutiovaikutuksilla, ja teoreettisessa mallissa näitä voidaan tarkastella "eristettyinä". Empiirisessä tutkimuksessa vaikeutena olisi mm. verojen havaittujen vaikutusten luotettava erottelu tulo- ja substituutiovaikutuksiin. Teoreettisilla tuloksilla on merkitystä sekä suuntaa-antavina politiikkajohtopäätöksinä että perustana numeerisille tai empiirisille analyyseille.

Mallin kehittelyn (luku 3) lähtökohdaksi valittiin Fisherin kulutus-säästämismalliin perustuva kahden periodin malli. Kun perusmallin päätösongelmana on annetun puuvarannon hakkuiden ajoitus, muotoilu kuvaa luontevasti lyhyen aikavälin tarjontapäätöksiä, joiden analyysiin sitä on käytetty. Optimikiertoaikamalliin verrattuna etuna on ennen kaikkea analyyttinen yksinkertaisuus. Aikaisempien versioiden rajoitusten poistamiseksi mallia laajennetaan käsittelemällä päätösmuuttujana myös metsänhoitoinvestointeja sekä johtamalla ratkaisu pitkän aikavälin tarjonnalle. Lyhyen ja pitkän aikavälin tarjonta osoittautuvat yhtäpitäviksi uusiutuvien luonnonvarojen jatkuva-aikaisten mallien ratkaisukäsitteiden kanssa.

Metsäverojen vaikutukset: positiivinen analyysi

Analysoitaessa metsäverojen vaikutuksia luvuissa 4 ja 5 tavoitefunktion argumenttina on vain kulutus, ts. puuntuotannosta saatavat tulot. Tehokkuusnäkökulmasta epärelevanttien tulovaikutusten eliminoimiseksi ja analyysin yksinkertaistamiseksi oletetaan täydelliset pääomamarkkinat ja täydellinen ennakkotietämys.

Näiden oletusten vallitessa hakkuista ja puustosta riippumaton "puhdas" pinta-alavero on neutraali. Myyntiverojen vaikutukset ovat verrattavissa ko. periodin kantohinnan muutoksiin. Veroasteen ajalliset vaihtelut vaikuttavat päätöksiin. Suhteellinen myyntivero voi kuitenkin olla neutraali siinä tapauksessa, että metsänhoitokustannukset ovat täydellisesti vähennettävissä ja veroasteen oletetaan pysyvän ajallisesti vakaana. *Ad valorem* -omaisuusvero puolestaan vaikuttaa kuten vastaava korkokannan nousu ja aikaistaa puuston realisointia. Myynti- ja omaisuusverojen vaikutukset metsänhoitoinvestointeihin ja pitkän ajan tarjontaan ovat epäselviä tai negatiivisia. Pitkän aikavälin tulokset ovat jokseenkin samoja kuin kiertoaikamallista epäsuorasti saatavat (verotuksen ajoitusvaikutuksia ei kiertoaikamallissa ole tiettävästi tarkasteltu).

Metsäverojen suhteellinen tehokkuus: normatiivinen analyysi

Vaihtoehtoisten metsäverojen haluttavuutta taloudellisen tehokkuuden näkökulmasta tarkastellaan luvussa 5. Lähtökohtana on, että pääomamarkkinoiden ollessa tehokkaat ja vinouttavien verojen puuttuessa yksityisen metsänomistajan optimaaliset päätökset vastaavat myös koko talouden kannalta optimaalista ratkaisua.

Johtopäätökset eroavat aiemmin usein esitetyistä – monesti vain epäsuorasti perustelluista – käsityksistä. Aikaisemmissa tutkimuksissa on eräitä poikkeuksia lukuun ottamatta jätetty huomiotta muut metsänomistajan päätöksiin vaikuttavat verot. Tässä työssä sen sijaan lähdetään siitä, että aiemmista verotuksellisista vinoutumista vapaan talouden oletus ei yleensä sovi reaalisten talouksien kuvaukseksi. Tällöin myös siihen perustuvat politiikkajohtopäätökset voivat olla harhaanjohtavia.

Kun muita metsänomistajan päätöksiin vaikuttavia veroja ei oleteta olevan, tehokkaita ovat neutraalit metsäverot, ts. puhdas pinta-alavero tai suhteellinen myyntivero edellä esitetyin varauksin. Sen sijaan (ei-neutraali) *ad valorem* -omaisuusvero ei ole tehokas, ja siihen kohdistunut kritiikki on tässä tapauksessa perusteltua.

Kun otetaan huomioon vaihtoehtoisten sijoitusten tuottojen tuloverotus (korkomenojen vähennysoikeus), pääoman yksityinen vaihtoehtoiskustannus on kansantaloudellista vaihtoehtoiskustannusta alempi eikä lähtötilanne ole tehokas. Tällöin pinta-ala- tai myyntiverotus eivät ole allokatiivisesti tehokkaita, koska neutraalin metsäveron ja muiden pääomatulojen verotuksen yhdistelmä ei ole kokonaisuutena neutraali. Tehokkuus edellyttää metsäverotusta, joka kumoaa muiden pääomatulojen verokohtelun puuston realisointia viivyttävän vaikutuksen ja palauttaa näin yksityis- ja kansantaloudellisesti optimaalisten päätösten vastaavuuden. Tämän ehdon täyttävä veroaste voidaan ratkaista *ad valorem* -omaisuusverolle.

Ad valorem -omaisuusveron haitoista esitetyt käsitykset eivät siis ole välttämättä perusteltuja. Siinä tapauksessa, että muita pääomatuloja verotetaan ja korkomenot ovat vähennyskelpoisia, asianmukaisesti asetettu omaisuusvero voi päin vastoin edistää pääomien tehokasta kohdentumista puuston ja muiden varallisuusmuotojen välillä. Tuloverotus sen sijaan on tehokas vain, jos verotettava metsätulo määritellään kertymä- eikä realisointipohjaisena.

Maisema- ja virkistysarvojen vaikutus

Luvussa 6 tavoitefunktioon sisällytetään kulutuksen lisäksi metsän markkinattomat ympäristöhyödyt puuvarannon funktiona. Paitsi perusmallin laajennuksena, muotoilua käytetään tutkittaessa verotustulosten herkkyyttä metsänomistajan ja/tai yhteiskunnan tavoitteiden suhteen.

Optimiratkaisua kuvaavat ehdot sisältävät tässä tapauksessa puuvarannon rajahyötyä vastaavan termin, joka merkitsee lyhyellä aikavälillä pienempiä hakkuita (suurempaa optimivarantoa). Puhdas pinta-alaverokaan ei ole neutraali syntyvien tulovaikutusten vuoksi, ja myös vakioisella myyntiverolla on substituutiovaikutuksia.

Metsäverojen suhteellista tehokkuutta koskevat johtopäätökset pysyvät kuitenkin melko muuttumattomina. Jos metsänomistajat ottavat markkinattomat hyödyt huomioon (ts. yhteiskunnalla ei ole tarvetta erityisesti edistää verotuksen avulla enempää ympäristöhyötyjen tuotantoa kuin hakkuitakaan), puhdas pinta-alavero on tehokas jos metsänomistajan päätöksiin vaikuttavia veroja ei ennestään ole. Jos taas muita pääomatuloja verotetaan, tehokkuus edellyttää *ad valorem* -omaisuusveroa samalla veroasteella kuin ympäristöhyötyjä huomioon ottamatta (luku 5). Jos yksityiset metsänomistajat taas eivät ota em. ulkoisvaikutuksia huomioon, tarkoituksenmukainen omaisuusveroaste on alempi kuin perustapauksessa. Myyntiverotus sen sijaan ei osoittaudu tehokkaaksi missään luvussa 6 käsitellyistä tilanteista.

Suomen metsäverotus

Luvussa 7 käsitellään ensiksi yksityiskohtaisemmin Suomessa perinteisesti sovellettua pinta-alaverotusta v. 1991 jälkeisessä "modifioidussa" muodossaan. Toiseksi käsitellään myyntiverotusta, johon siirrytään v. 1993 alkaen ulottamalla yhtenäinen pääomatulojen verokanta metsätalouden realisoituun tuloon. Analyysissä otetaan huomioon muiden pääomatulojen verotuksen (korkovähennysten) vaikutus. Jotta verotus kokonaisuutena kohtelisi metsän käsittelypäätöksiä neutraalisti, metsäverotuksessa tulisi tällöin ottaa tavalla tai toisella huomioon tilakohtaiset hakkuumahdollisuudet, ts. puuvaranto ja/tai sen muutokset.

Vuoden 1991 metsäverouudistuksessa oli tavoitteena mm. edistää vanhojen metsien uudistamista laajentamalla uudistusalan taimikoiden verovapautta. Tulosten mukaan ei kuitenkaan ole täysin selvää, onko uudistusalojen verovapaudella toivottu vaikutus uudistushakkuiden ajoitukseen, jos sen saantimahdollisuus on pysyvä. Toisaalta myyntiverotukseen siirtymisen taustalla ovat muut kuin tehokkuusnäkökohdat, erityisesti näennäinen yhdenmukaisuus muiden pääomatulojen verotuksen kanssa. Uudistuksen valmistelussa ei ole otettu huomioon järjestelmän kokonaisvaikutuksia puuston realisointipäätöksiin. Vaikka puunmyyntituloon kohdistuva vero itsessään olisikin neutraali, se ei ole taloudellisesti tehokas yhdistyessään puuston realisointia viivyttävään muiden pääomatulojen verotukseen (siirtymäkauden tilapäiset vaikutukset ovat oma lukunsa).

Johtopäätöksiä

Tutkimuksessa arvioidaan metsäverotusta pääosin taloudellisen tehokkuuden näkökulmasta (luvut 5–7). Luvussa 8 käsitellään – verojen kohtaannon, ts. tulonjako- ja hintavaikutusten ohella – muita kriteereitä, jotka veromuodon valinnassa on otettava huomioon. Horisontaalista ja vertikaalista oikeudenmukaisuutta (equity) tarkastellaan lähtien näkemyksestä, jonka mukaan 'oikeudenmukaisen' metsäverotuksen tulisi ottaa huomioon omaisuuden tulonansaintakyky, jota osoittavat metsän hakkuumahdollisuudet. Myös eri järjestelmien informaatiovaatimuksia ja niihin liittyviä hallintokustannuksia tarkastellaan lyhyesti. Seuraavassa hahmotellaan lopuksi yleisarviota eri metsäverovaihtoehdoista.

(1) Puhdas pinta-alavero on taloudellisesti tehokas vain, jos muita metsänomistajan päätöksiin vaikuttavia

veroja ei ole. Sitä voidaan pitää oikeudenmukaisena pitkällä aikavälillä muttei välttämättä lyhyellä. Kasvupaikkaluokituksiin liittyy huomattavia kustannuksia. Suomessa käytetty modifioitu pinta-alaverotus on puhdasta pinta-alaverotusta oikeudenmukaisempi ja vastaa paremmin tehokkuutta silloin, kun muita pääomatuloja verotetaan, mutta merkitsee korkeampia toimeenpanokustannuksia.

(2) Myyntiverotus on taloudellisesti tehoton erityisesti siinä tapauksessa, että muita pääomatuloja verotetaan (korkomenot ovat vähennyskelpoisia). Se on myös heikosti yhteensopiva horisontaalisen ja vertikaalisen oikeudenmukaisuuden kanssa, koska hakkuumahdollisuuksia ei oteta huomioon. Yksinkertaiset sovellukset (lähdevero) tarjoavat hallinnollisia etuja, jotka kuitenkin paljolti menetetään, jos vähennykset otetaan yksityiskohtaisesti huomioon tilakohtaisina.

(3) *Ad valorem* -omaisuusvero on asianmukaisesti asetettuna taloudellisesti tehokas silloin, kun muita pääomatuloja verotetaan. Sitä voidaan pitää pinta-ala- ja myyntiveroja oikeudenmukaisempana sikäli, että hakkuumahdollisuudet tulevat huomioon otetuiksi. Toisaalta se merkitsee korkeampia toimeenpanokustannuksia. Saavutettavissa olevien kansantaloudellisten hyötyjen arviointi ja vertailu lisäkustannusten kanssa vaatisi numeerisen yleisen tasapainon mallin käyttöä.

Appendix 1. Comparison of the results with the rotation model

For a meaningful comparison, the assumptions of both models should be made as similar as possible. First, assume forest growth depends only on stand age or the growing stock (for example, E is institutionally fixed at a given level). Using the same notation as in end notes 1 and 3, Chapter 2, the basic Faustmann formula can be written as $LEV(t) = [pf(t)e^{-rt} - C] / [1 - e^{-rt}]$. The optimal rotation will be

$$\text{(A1.1)} \quad t^* = t^*(\underset{-}{p}, \underset{-}{r}, \underset{+}{C})$$

(e.g. Johansson & Löfgren 1985). Given that long-run timber supply is determined by $h^F = f(t^*)/t^*$ (Clark 1976, Hyde 1980) and using the graphical argument by Jackson (1980) for long-run results, the implied short and long-run supply (H^F and h^F, respectively) can be characterized as

$$\text{(A1.2)} \quad H^F = H^F(\underset{+}{p}, \underset{+}{r}, \underset{-}{C}), \; h^F = h^F(\underset{-}{p}, \underset{-}{r}, \underset{+}{C}).$$

Note that the rotation model assumes that a regeneration cost occurs every time the stand is clearcut. In the two-period model, an equivalent assumption incorporates a regeneration cost proportional to the current harvest volume. Then, the first-period budget constraint becomes $c_1 = p_1H_1 - w\,\eta\,H_1 - S = (p_1 - w\,\eta)H_1 - S$, where η is a proportionality parameter. For short and long-run supply (long-run supply now defined as $h = F(Q - H)$, this implies

$$\text{(A1.3)} \quad H = H(\underset{+}{p}, \underset{+}{r}, \underset{-}{w}; \underset{+}{p_1}, \underset{-}{p_2}, \underset{1}{Q}), \; h = h(\underset{-}{p}, \underset{-}{r}, \underset{+}{w}).$$

Secondly, consider management intensity as a choice variable. Following Chang (1983), the generalized rotation model $LEV(t,m) = [pf(t,m)e^{-rt} - wm] / [1 - e^{-rt}]$ implies

$$\text{(A1.4)} \quad t^* = t^*(\underset{-/?}{p}, \underset{?/-}{r}, \underset{+/?}{w}), \; m^* = m^*(\underset{+/?}{p}, \underset{?/-}{r}, \underset{-/?}{w})$$

where w represents Chang's planting cost (the site preparation cost would make little difference). For short and long-run supply, $h^F = f(t^*,m^*) / t^*$, (A1.4) implies

$$\text{(A1.5)} \quad H^F = H^F(\underset{+/?}{p}, \underset{?/+}{r}, \underset{-/?}{w}), \; h^F = h^F(\underset{+/?}{p}, \underset{-/?}{r}, \underset{-/?}{w})$$

(Hyde 1980, Jackson 1980). Ambiguities arise because the signs depend on $sgn(f_{tm})$ and $sgn(pf_{tm} - wre^{rt})$ (Chang 1983). On the other hand, the two-period model with endogenous management intensity implies

$$H = H(\underset{?}{p}, \underset{+/?}{r}, \underset{?}{w}; \underset{+}{p_1}, \underset{-/?}{p_2}, \underset{1}{Q})$$

$$\text{(A1.6)} \quad E = E(\underset{+}{p}, \underset{-/?}{r}, \underset{-}{w}; \underset{?}{p_1}, \underset{+/?}{p_2}, \underset{0}{Q})$$

$$h = h(\underset{+/?}{p}, \underset{-/?}{r}, \underset{-/?}{w})$$

(see text). The signs depend on $sgn(F_{KE})$, uncertain results appearing when $F_{KE} < 0$.

Appendix 2. Conceptual remarks on the excess burden

Suppose the "small" individual forest owner initially faces a horizontal demand curve D, i.e., a given stumpage price p_0 (Fig. A2.1). With the short-run timber supply curve depicted by S, the quantity sold will be q_0. This implies that the seller's surplus is the triangle p_0ea. After a proportional yield tax at rate γ is imposed, the forest owner will receive $(1 - \gamma)p_0$ for a unit of timber sold at p_0 per unit; i.e. the demand curve perceived after the tax becomes D'. While the buyer's price remains at $p_b = p_0$, the seller's effective price will be p_s and the quantity sold is reduced to q_1. Consequently, the seller's surplus is reduced to $p_se'a$, while the amount collected as tax revenue is $p_bbe'p_s$. As the reduction in the seller's surplus $(p_bee'p_s)$ is greater than the tax revenue, the excess burden of the yield tax is the shaded triangle bee' (cf. Rosen 1985, p. 285).

To illustrate the first contention – that the excess burden does not follow only from a reduction in output but even a subsidy generates a positive excess burden – suppose a proportional subsidy at rate σ is introduced

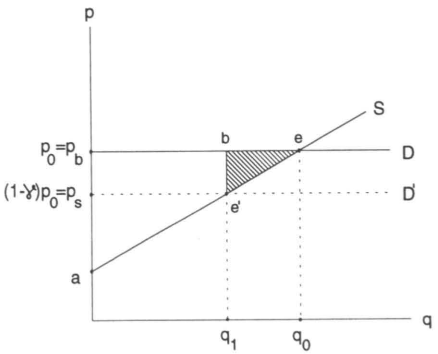

Fig. A2.1. The excess burden of the yield or sales tax (shaded area).

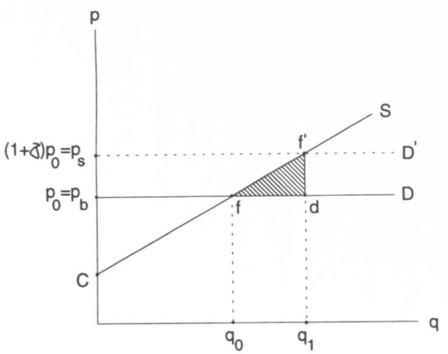

Fig. A2.2. The excess burden of a subsidy.

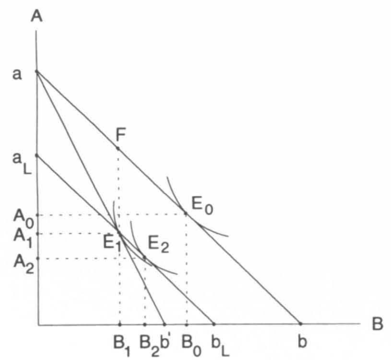

Fig. A2.3. The total, substitution, and income effects of a commodity tax levied on commodity B.

(Fig. A2.2). At buyer's price $p_b = p_0$, the seller will perceive the demand curve as D' and receive $(1 + \sigma)p_0$ per cubic meter sold, so that the quantity supplied increases to q_1. The seller's surplus increases from p_0fc to $p_sf'c$. However, the total cost of the subsidy is the rectangle $p_sf'dp_b$, which exceeds the increase in seller's surplus by the area f'df. In other words, the subsidy generates an excess burden represented by the shaded triangle (cf. Rosen 1985, p. 288). Recalling Chapter 3, the timber supply curve represents the balance between the marginal revenue and marginal opportunity cost of the current harvest. Thus, an excess burden arises since the subsidy induces the forest owner to cut units of timber that are valued at less than their true social opportunity cost (present value of growth forgone). This is reflected in that to the right of q_0, line D is below the supply curve.

The third contention – that only substitution effects are relevant when defining the excess burden – can easily be made clear by following Rosen (1985, p. 276–279) who uses a pure consumption model with two commodities, A and B. In Fig. A2.3, the consumer's budget constraint without taxes is line ab, the slope of which reflects the relative price of B in terms of A. Given normally shaped indifference curves, a consumption bundle such as (A_0,B_0) at point E_0 is chosen. Suppose a proportional tax is imposed on B so that its after-tax price increases by the tax per cent. With the price of A unaltered, the relative price of B changes as reflected by the new budget line ab'. The consumer's choice now is (A_1,B_1) and the commodity tax he/she pays is the vertical distance E_1F. At point E_1, the consumer is worse off than initially, as E_1 is on a lower indifference curve. But suppose the same amount of tax were collected as a lump sum. The original budget line ab would shift down by the constant distance E_1F with its slope unchanged, because lump-sum taxes leave relative prices unchanged. The budget line becomes a_Lb_L, and the most preferred bundle is (A_2,B_2).

Note that, although the same amount of tax is collected, the consumer is left better off when a lump-sum tax is used. Thus, the excess burden is the *reduction of utility in excess of that which would occur if the given amount of tax were collected as a lump sum* (Rosen 1985, p. 278). In Fig. A2.3, this shows in that E_2 is on a higher indifference curve than E_1. Further, note that lump-sum taxes have income effects only. The result means that the excess burden of a tax is represented by the loss of utility above and beyond the income effect, i.e., by *the compensated or substitution effects alone*. In Fig. A2.3, the movements from E_0 to E_1 and E_0 to E_2, respectively, represent the uncompensated (total) reaction and the income effect. The movement from E_2 to E_1 indicates the excess welfare loss due solely to a change in relative prices.

Appendix 3. A switch between gross yield and *ad valorem* property taxes

As both taxes are nonneutral, the comparison is not as simple. Denoting the target level of steady state tax revenue by T^0 and setting d = 0 for simplicity, it can be written

(A3.1) $T^0 = \gamma phr^{-1} + \alpha pKr^{-1} = \gamma phr^{-1} + \alpha p\,\Phi(h,E)r^{-1}$.

By h = F(K,E), the growing stock has been replaced by writing K = Φ(h,E), where $\Phi(.)$ is the inverse function of F(K,E). As $F_K > 0$, i.e. F(.) is monotonic in K, over the relevant range K < M the inverse function is unique with $\Phi_h(.) > 0$ for all K < M. Totally differentiating w.r.t. γ, α and h with T^0 unchanged gives

(A3.2) $dT^0 = 0 = phr^{-1}d\gamma + p\,\Phi(h,E)r^{-1}d\alpha + [\gamma pr^{-1} + \alpha p\,\Phi_h(.)r^{-1}]dh.$

Solving for $d\gamma$, substituting into $dh = h_\gamma d\gamma + h_\alpha d\alpha$ and solving, the effect on long-run timber supply of a compensated switch between α and γ is obtained as

(A3.3) $$dh/d\alpha_{(\alpha,\gamma|T=T^0)} = \frac{h_\alpha - h_\gamma h^{-1}\Phi(.)}{1 + h_\gamma h^{-1}(\gamma + \alpha\Phi_h)} \gtreqless 0.$$

Regarding direct effects only, reducing γ will have a positive effect on h via E, while increasing α will have a negative effect via K. Thus, the total effect is *a priori* indeterminate.

Appendix 4. The expenditure tax

The expenditure tax implies choosing an individual's consumption expenditure, rather than income, as the base for direct taxation. For the lengthy debate on the relative merits of income vs. consumption as the tax base, the reader is referred to e.g. Musgrave (1985). In the present context, the expenditure tax will be defined as a given per cent of the relevant period's harvest revenue, net of management costs, minus net savings. That is, savings are excluded from the tax base, while borrowing is included. Interest income from the assets will be taxed only when withdrawn for consumption. The usual way to define a proportional tax-exclusive expenditure tax rate t^c (e.g. Koskela 1988) is by writing

(A4.1)
$$(1 + t_1^c)c_1 = p_1H_1 - wE - S$$
$$(1 + t_2^c)c_2 = p_2H_2 + (1 + r)S,$$

which is equivalent to

(A4.1')
$$c_1 = (1 + t_1^c)^{-1}[p_1H_1 - wE - S]$$
$$c_2 = (1 + t_2^c)^{-1}[p_2H_2 + (1 + r)S].$$

For notational simplicity, the expenditure tax rate will be represented by ε_i (i = 1,2), which is defined as follows:

(A4.2) $(1 + t_i^c)^{-1} = (1 - \varepsilon_i) \iff \varepsilon_i = t_i^c/(1 + t_i^c)$.

Inserting the definition in (A4.2) into the budget constraints in (A4.1'), the intertemporal budget constraint becomes $c_2 = (1 - \varepsilon_2)\{p_2[Q - H + F(Q - H,E)] + (1 + r)[p_1H - wE - (1 - \varepsilon_1)^{-1}c_1]\}$ and the first-order conditions for an interior solution are

(A4.3a) $U_{c_1} = u'(c_1) - \beta u'(c_2)(1 - \varepsilon_2)(1 - \varepsilon_1)^{-1}(1 + r) = 0$

(A4.3b) $U_H = \beta u'(c_2)(1 - \varepsilon_2)\{-p_2[1 + F_K] + p_1(1 + r)\} = 0$

(A4.3c) $U_E = \beta u'(c_2)(1 - \varepsilon_2)\{p_2F_E - w(1 + r)\} = 0.$

Consider, first, the consumption-savings decision characterized by (A4.3a). While distorted if $\varepsilon_1 \neq \varepsilon_2$, the consumption decision remains undistorted if $\varepsilon_1 = \varepsilon_2$. Secondly, the optimal harvesting and investment decisions are independent of the expenditure tax, whether constant or not, since β, u'(.), $(1 - \varepsilon_2) > 0$ in (A4.3b) and (A4.3c) so that the separation result continues to hold. Intuitively, the reason for neutrality is the tax being levied on timber revenue consumed in the particular year rather than the revenue obtained at harvest time. As the productive decisions are independent of consumption decisions, they have no direct link with a consumption tax.

In summary, an expenditure tax with a temporally invariable tax rate would be neutral with respect to both consumption-savings and forest management decisions. In fact, with all money invested in silviculture tax exempt, even a progressive expenditure tax would be neutral w.r.t. forest management decisions. This could be seen by letting $c_i = [1 - \varepsilon_i(b_i)]b_i$, where b is the tax base and $\varepsilon_i'(b) > 0$ to represent tax progression. Finally, note that a feature of expenditure taxation is involved in the Swedish yield taxation (see Aronsson 1986, 1988, 1990a,b). In order to alleviate the effects of progressive income taxation, a given fraction of harvest revenue can be deposited on a special "forest account" (skogskonto) and will not be taxable until withdrawn.

Appendix 5. *Ad valorem* property tax with inflation: solution and numerical examples

To explicitly consider an economy with inflation, write the future real stumpage price and real interest rate in terms of the nominal price/interest rate and the rate of inflation. The undistorted solution, first, involves

$$\text{(A5.1)}\quad r = r^* - \iota,\quad p_2 = p_2^*(1+\iota)^{-1}$$

where r^* is the nominal interest rate, p_2^* is the nominal future price, and ι is the rate of inflation by which p_2^* is to be deflated. Inserting these into the second-period budget constraint, the socially optimal allocation will be characterized by

$$\text{(A5.2a)}\quad 1 + F_K(.) = \frac{p_1}{p_2^*(1+\iota)^{-1}}\,[1 + (r^* - \iota)]$$

$$\text{(A5.2b)}\quad F_E(.) = \frac{w}{p_2^*(1+\iota)^{-1}}\,[1 + (r^* - \iota)].$$

To get the private solution, next introduce the capital income tax and *ad valorem* property tax. As the capital income tax is paid and deductions are made from the nominal interest, inflation has to be taken into account after the tax/deduction. The intertemporal constraint for real consumption then becomes

$$\text{(A5.3)}\quad c_2 = p_2^*(1+\iota)^{-1}H_2 + (1+r^*)S - \tau r^*S - \iota(1+r^*)S \approx p_2^*(1+\iota)^{-1}H_2 + \{1 + [r^*(1-\tau) - \iota]\}S,$$

where a small term $-\iota r^*$ has been dropped for clarity. That is, the private effective, after-tax real interest rate will be approximately equal to $r^*(1-\tau) - \iota$ rather than $r^* - \iota$. The second-period property tax (its real burden), on the other hand, is $\alpha_2 p_2^*(1+\iota)^{-1}K_2$.

Inserting both τ and α, the private optimum will be

$$\text{(A5.4a)}\quad 1 + F_K(.) = \frac{p_1}{p_2^*(1+\iota)^{-1}}\,(1+\alpha_1)\,[1 + r^*(1-\tau) - \iota]$$

$$\text{(A2.4b)}\quad F_E(.) = \frac{w}{p_2^*(1+\iota)^{-1}}\,[1 + r^*(1-\tau) - \iota].$$

The appropriate property tax rate α can be solved by equating the R.H.S's of (A5.2) and (A5.4) (note that the deflated price terms vanish as the public and private inflationary expectations are implicitly assumed to be equal). As earlier, the latter equality implies $r^*\tau = 0$, which is untrue. The former equality alone gives

$$\text{(A5.5)}\quad \alpha_1 = \frac{r^*\tau}{1 + r^*(1-\tau) - \iota}.$$

As an approximation, $\alpha \approx r^*\tau$. That is, the efficient optimal *ad valorem* property tax rate in an economy with inflation equals the nominal, rather than real, pre-tax interest rate multiplied by the capital income tax rate. With $\iota = 0$, (A5.5) reduces to (5.25). To give an idea of the magnitude of the required property tax rate, numerical examples of the effective interest rate and the property tax rate are given for some "typical" values of τ, r^* and ι. They are based on the following assumptions.

(1) A nominal interest rate at 10% is used to represent an average "market interest rate". For the capital income tax rate, 15% and 30% are used. (The former coincides with the 1992 level of the income tax on savings in Finland. The latter is close to the impact of interest charge deductions in the early 1990's, with 75% deductible, at a 40% marginal tax rate).

(2) The average rate of inflation is assumed to be 6%/yr. With a 10% nominal interest rate, this implies that the real, before-tax market rate of interest is 4%. This coincides with a reasonable estimate of the risk-free social discount rate (for the main approaches, see Dasgupta & Pearce 1978). In the case of Finland, such a rate can be taken to fall within the range of 3–5% (Björk 1984). The social time preference rate can be estimated to be 3–4%. The private rates of return have been 6–7%, from which the private risk premium (e.g. 2%) must be deducted to arrive at the social opportunity cost of capital (Arrow & Lind 1970).

(3) To allow for the difference between saving and borrowing rates in the capital market, assume that the nominal savings rate (r_s) is 8% with τ at 15 or 30%, while the borrowing rate (r_b) is 12% with τ at 30%. In this case, it must be noted that the optimal property tax is a rate that effectively restores the equality of the private, after-tax real saving/borrowing rate with the *social* discount rate (here, 4%), now different from the untaxed private interest rates. By (A5.2a) and (A5.4a), this can be solved from the equality $1 + (r^* - \iota) = (1+\alpha_1)[1 + r^*_{s,b}(1-\tau) - \iota]$.

The results are given in Table A5.1. First, comparing the lines A and B shows that the distortions in the effective interest rate caused by the capital income taxation are significant. For example, a 10 % nominal interest rate with a 6% rate of inflation implies only a 1%, rather than 4%, effective interest rate if interest charge deductions at 30% are imposed. Secondly, the values for α vary significantly, ranging from 1.5 to 4.4%. In some cases, the "fully corrective" tax rates would obviously lead to unrealistically high tax burdens (see end note 7, Chapter 7).

Table A5.1. Undistorted and after-tax private real interest rate and efficient property tax rate[1] for varied rates of capital income tax (τ) and nominal interest (r^*).

	r^*= 0.10		r_s^*= 0.08		r_b^*= 0.12
	τ=0.15	τ=0.30	τ=0.15	τ=0.30	τ=0.30
A. Undistorted					
$r_u = r^* - \iota$	0.04		0.02		0.06
B. After-tax					
$r_\tau = r^*(1-\tau) - \iota$	0.025	0.01	0.008	–0.004	0.024
C. Optimal tax rate	0.015	0.03	0.032	0.044	0.016

[1] At 6% rate of inflation and 4% real social discount rate

Appendix 6. Optimal management intensity with nontimber benefits

With the management intensity E included in the model of section 6.2, the second-period standing stock becomes $K_2 = Q - H_1 + F(Q - H_1, E_1) - H_2$ and the first-period budget constraint will be $c_1 = p_1H_1 + I - S - wE_1$. The problem will be maximizing the relevant objective function w.r.t. c_1, H_1, E_1, and H_2 ($E_2 = 0$ similarly to the separation case as it is not assumed to affect the second-period stock). The solution becomes

$$\text{(A6.1a)}\quad V_{c_1} = u'(c_1) - \beta u'(c_2)(1+r) = 0$$

$$\text{(A6.1b)}\quad V_{H_1} = \beta u'(c_2)(1+r)p_1 - \beta v'(K_2)[1 + F_{K_1}(.)] - v'(K_1) = 0$$

$$\text{(A6.1c)}\quad V_{E_1} = -u'(c_2)(1+r)w + v'(K_2)\,F_{E_1}(.) = 0$$

$$\text{(A6.1d)}\quad V_{H_2} = u'(c_2)p_2 - v'(K_2) = 0.$$

Solving (A6.1d) for $v'(K_2)$, substituting into (A6.1b) and rearranging, the cutting rule becomes $\beta u'(c_2)\{-p_2[1 + F_{K_1}(.)] + (1+r)p_1\} = v(K_1)$, which is similar to (6.6). Also substituting $v'(K_2) = u'(c_2)p_2$ into (A6.1c), the optimal management intensity can be characterized by

$$\text{(A6.3)}\quad u'(c_2)\{p_2\,F_{E_1}(.) - (1+r)w\} = 0.$$

Clearly, (A6.2) holds if and only if $\{.\} = p_2\,F_{E_1}(.) - (1+r)w = 0$, which is formally equivalent to the condition that the marginal return equals marginal factor cost in e.g. (3.10b). That is, the optimal management intensity decision is *separable* from the consumption and harvesting decisions, and the inclusion of nontimber benefits will not affect its optimal level as far as only direct effects are considered. The reason is that, according to (A6.1c), the marginal utility (via an increase in K_2) and marginal cost (via a reduction in current consumption) w.r.t. E change symmetrically. On the other hand, because H_1 is reduced so that K_1 increases, *ceteris paribus*, the marginal product $F_E(.)$ and consequently E^* are indirectly affected through the interaction effect. As $\text{sgn}(\Delta E^*) = \text{sgn}(F_{KE})$, in particular the regeneration ($F_{KE} < 0$) is reduced in the sense that fewer hectares are cut and reforested. (The reforestation intensity on hectares actually clearcut – or, where no standards are imposed by the law, the forest owner's propensity to reforest – may well increase, as suggested in Hyberg & Holthausen (1989)). In contrast, if intensive silvicultural measures directly impute disutility, i.e. $V = V(c_i, K_i, E_i)$, the management intensity decision will no longer be separable but simultaneously determined with consumption and harvesting decisions (besides, E_2 would also matter).

Appendix 7. The decomposition of comparative statics results with nontimber benefits

The first-order conditions (6.5) of the utility maximization problem implicitly define uncompensated reaction equations which express c_1, H_1, and H_2 as functions of the exogenous variables: $c_1 = c_1(I, p_1, p_2, r, Q)$, $H_1 = H_1(I, p_1, p_2, r, Q)$, and $H_2 = H_2(I, p_1, p_2, r, Q)$. Substituting these into the objective function V, an indirect utility function Y is obtained which indicates the maximum attainable utility V^0 under given values of the exogenous variables:

$$\text{(A7.1)}\quad V^0 = Y(I, p_1, p_2, r, Q) = u(c_1(.)) + v(K_1) + \beta\{u(c_2(.)) + v(K_2)\}.$$

By the envelope theorem (e.g. Varian 1978), the effects on the maximum attainable utility Y of changes in exogenous variables can be written as

$$Y_I = \beta u'(c_2)(1+r) > 0$$

$$Y_{p_1} = \beta u'(c_2)(1+r)H_1 = H_1\,Y_I > 0$$

$$Y_{p_2} = \beta u'(c_2)H_2 = H_2(1+r)^{-1}\,Y_I > 0$$

$$\text{(A7.2)}\quad Y_r = \beta u'(c_2)(p_1H_1 + I - c_1) = \beta u'(c_2)S = Y_I S(1+r)^{-1} \gtreqless 0 \text{ as } S \gtreqless 0$$

$$Y_Q = v'(K_1) + \beta v'(K_2)(1+F') = \beta u'(c_2)(1+r)p_1 = p_1\,Y_I > 0.$$

On the other hand, the current exogenous income can be written as a function (G) of the other exogenous factors and maximum utility V^0 so that $I = G(p_1, p_2, r, Q, V^0)$. Further, substituting G(.) for I into Y implies $Y(G(p_1, p_2, r, Q, V^0), p_1, p_2, r, Q) = V^0$. Consider next the compensation in terms of current nonforest income I, which is required to keep the maximum attainable utility unchanged as some other exogenous variable changes. Differentiating Y(.) with respect to exogenous factors, while holding the forest owner's utility unchanged at V^0 (i.e., $dY = 0$), it is obtained for p_1, for example, $Y_{p_1} + Y_I\,G_{p_1} = 0$. Given that $Y_{p_1} = H_1\,Y_I$ by (A7.2), the required compensation can be solved w.r.t. p_1 and similarly for other factors:

$$G_{p_1} = -Y_{p_1}\,Y_I^{-1} = -H_1$$

$$G_{p_2} = -H_2(1+r)^{-1}$$

$$G_r = -S(1+r)^{-1}$$

$$G_Q = -p_1.$$

Next, define the compensated reaction equations which correspond to the solution of the dual problem, i.e. the minimum level of exogenous income which can retain the constant utility level V^0 at given values of other exogenous factors. Substituting G(.) for I into the uncompensated equations gives the following relationship between the *uncompensated and compensated timber supply functions* H(.) and $H^c(.)$, respectively:

(A7.4) $H(G(p_1,p_2,r,Q,V^0),p_1,p_2,r,Q) = H^c(p_1,p_2,r,Q,V^0)$.

Differentiating (A7.4) with respect to p_1, for example, yields $H_{p_1} + H_I G_{p_1} = H^c_{p_1}$ and, since $G_{p_1} = -H$ by (A7.3),

(A7.5) $H_{p_1} = H^c_{p_1} + HH_I$.

According to (A7.5), the total effect on the current harvest of a change in current stumpage price, H_{p_1}, can be decomposed into (a) the substitution or compensated effect $H^c_{p_1}$ and (b) an income effect. The latter is measured by the product of the marginal effect of exogenous income, H_I, and quantity harvested, H. The other effects can be similarly decomposed. For the income effects, the impact of exogenous income is first solved in the conventional manner. By Cramer's rule,

$$\partial H/\partial I = D^{-1}\begin{vmatrix} V_{11} & -\partial V_1/\partial I & V_{13} \\ V_{21} & -\partial V_2/\partial I & V_{23} \\ V_{31} & -\partial V_3/\partial I & V_{33} \end{vmatrix}$$

To sign this, differentiate the first-order partial derivatives in (6.5) with respect to I, as well as all endogenous variables. Substituting the relevant partials, using $D < 0$ (from second-order conditions) and simplifying, the result in (6.8a) is obtained. Clearly, $H_I < 0$ since D, u"(.), v"(.) < 0 and [.] > 0 according to first-order conditions.

The substitution effect refers to a *compensated* change in some exogenous variable j, i.e., the income and utility of consumption are assumed to remain unchanged. Hence, the terms V^c_{1j}, V^c_{2j}, and V^c_{3j}, which are required to determine the substitution effects, are obtained by differentiating the first-order partials of V(.) with respect to j while treating the term $u'(c_2)$ as a constant. The latter is because the hypothetical compensation keeps the total income and comsumption level c_2 unchanged. With c_2 unchanged, $u'(c_2)$ remains constant (consequently, $u'(c_1)$ and $v'(K_2)$ also are constants by (6.5a) and (6.5c), respectively). For p_1, for example, $V^c_{1p_1} = 0$, $V^c_{2p_1} = \beta u'(c_2)(1 + r)$ and $V^c_{3p_1} = 0$, so its compensated effect is

$$\partial H^c/\partial p_1 = D^{-1}\begin{vmatrix} V_{11} & 0 & V_{13} \\ V_{21} & -\beta u'(c_2)(1+r) & V_{23} \\ V_{31} & 0 & V_{33} \end{vmatrix}$$

Similarly solving w.r.t. other factors and simplifying, the substitution effects become

$$H^c_{p_1} = -D^{-1}\beta u'(c_2)(1 + r)\ \{\beta u''(c_1)[u''(c_2)p_2^2 + v''(K_2)] + \beta^2 u''(c_2)v''(K_2)(1 + r)^2\} > 0$$

$$H^c_{p_2} = D^{-1}\beta u'(c_2)\{u''(c_1)\beta[u''(c_2)(1 + r)p_1p_2 + v''(K_2)] + \beta^2 u''(c_2)v''(K_2)(1 + r)^2(1 + F')\} < 0$$

$$H^c_r = -D^{-1}\beta^2 u'(c_2)\ \{\beta u''(c_2)v''(K_2)(1 + r)p_2(1 + F') + p_1u''(c_1)[u''(c_2)p_2^2 + v''(K_2)]\} > 0$$

$$H^c_Q = D^{-1}\beta v'(K_2)F''\{\beta u''(c_1)[u''(c_2)p_2^2 + v''(K_2)] + \beta^2 u''(c_2)v''(K_2)(1 + r)^2\} > 0.$$

Appendix 8. Long-run steady state effects of the modified site productivity tax

Setting p, ε, and Γ constant over time to represent the stationary case, $p_i + x_i = p + x$ and the terms $p + x$ in (7.4a) cancel out. According to

(A8.1a) $H_x = -D^{-1}F_EF_{KE} \geq 0$ as $F_{KE} \leq 0$
(A8.1b) $E_x = -D^{-1}F_EF_{KK} > 0$,

the permanent option for a tax exemption encourages final fellings only indirectly through the profitability of reforestation investments (the direct effects with $F_K - r^0$ in (7.6) vanish). The impacts of δ and τ remain qualitatively unchanged. Using Eq. (4.19) and the results for H and E, the impacts on long-run timber supply become

(A8.2a) $h_x = -D^{-1}F_E[F_EF_{KK} - F_KF_{KE}] \substack{>0\\=?}$ as $F_{KE} \underset{<}{\overset{=}{=}} 0$

(A8.2b) $h_\delta = -D^{-1}w(1 + r^0)[F_EF_{KK} - F_KF_{KE}] \substack{>0\\=?}$ as $F_{KE} \underset{<}{\overset{=}{=}} 0$

(A8.2c) $h_\tau = -D^{-1}\{F_K[r(p + x)F_{EE} - (1 - \delta)wF_{KE}] + F_E[(1 - \delta)wF_{KK} - r(p + x)F_{KE}]\} \substack{>0\\=?}$ as $F_{KE} \underset{<}{\overset{=}{=}} 0$.

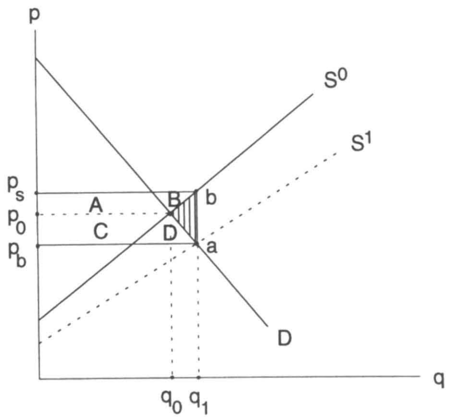

Fig. A8.1. The excess burden of a subsidy-driven increase in long-run timber supply (shaded area).

The harvest subsidy x has a positive direct effect through the management intensity and an indirect effect, which is negative or zero. Similarly, the management subsidy δ has a positive direct effect through E. The capital income tax τ has positive direct effects associated with an increase in both growing stock and management intensity. Assuming the direct effects dominate, (A8.2) implies

(A8.3) $h = \underset{+\ \ +\ \ +}{h(x,\ \delta,\ \tau)}$.

Reforestation subsidies (δ) will augment the steady state timber production, as does the capital income tax τ, and $h_x > 0$ in fact suggests that the modified site productivity tax, with regeneration areas exempted, results in a higher long-run timber supply than a neutral tax or no forest taxes at all. In summary, both the tax exemptions and deductions and the capital income tax explicitly or implicitly subsidize forestry and increase the potential long-run timber supply. While this might seem desirable, it should be noted that *any* distortion of an efficient allocation implies a positive excess burden. In Fig. A8.1, the effect on long-run supply is represented by the shift from S^0 to S^1. The excess burden (cf. Auerbach 1985, Rosen 1985) is the cost of the tax subsidy (tax revenue lost), p_babp_s, in excess of the total increase in the sellers' and buyers' surpluses, (A + B) + (C + D). The undistorted supply curve S^0 indicates the price that covers the marginal opportunity and factor cost of producing any given quantity of timber. Accordingly, the excess burden arises because the extra units of timber between q_0 and q_1 are valued (along the demand curve) at less than their true social cost.

Appendix 9. Management distortions from capital income taxation: numerical examples

An *aggregate size dependent growth function* was estimated using the data from the National Forest Inventories (NFI) I through VII (Kuusela 1972, Yearbook of … 1989) and the updated data on the growing stock and timber growth in 1990 (Suomen metsävarat … 1990, Suomen metsien … 1990). The generally used logistic growth function (e.g. Clark 1976), augmented by a dummy variable, was employed in the form

(A9.1) $F(K) = \rho_0 K - \dfrac{\rho_0}{C}K^2 + \varphi D$,

where K is the growing stock, ρ_0 is the intrinsic growth rate, and C is the maximum attainable stock (saturation level). The dummy variable D, with the values D = 1 for NFI VII, D = 2 for 1990 and D = 0 otherwise, was included to capture the distinct shift of the growth level indicated by the last two observations obviously due to the extensive forest improvement programs since mid-1960's (especially drainage of peatlands). The ordinary least squares (OLS) estimate at the first stage was

(A9.2) $F(K) = \underset{(6.20)}{0.06\,K} - \underset{(2.53)}{0.000016\,K^2} + \underset{(5.08)}{11.73\,D}$,

which may be compared with Kasanen's (1984) estimate for NFI I through VI (units are mill. cubic meters, $R^2 = 0.999$, and t values in parenthesis). To obtain the marginal productivity with respect to the growing stock at the current (1990) growth level, the coefficient of the dummy variable was used to shift the data points representing NFI I–VII to the current level. The growth figures from NFI I–VI were added by 10.0 mill. m^3 and NFI VII by 20.0 mill. m^3. The (hypothetical) fitted curve at the second stage became

(A9.3) $F(K) = \underset{(16.69)}{0.078\,K} - \underset{(6.68)}{0.000019\,K^2}$

($R^2 = 0.999$), according to which the marginal product of the growing stock is

(A9.4) $F'(K) = 0.078 - 0.000038\,K$.

Substituting F'(K) from (A9.4) into the cutting rule $F'(K) = r$ (given $p_1 = p_2 = p$), the optimal long-run equilibrium level of the growing stock K^* can be solved for any given discount rate r (see below).

r, %/yr	0	1.0	1.5	2.0	3.0	4.0
K^*, $10^6\ m^3$	2060	1797	1665	1533	1270	1007

To consider the management distortions in terms of the *optimal harvest age*, suppose the forest owner behaves as if he/she sought to maximize the present value of net revenue from timber growing,

(A9.5) $\underset{\{t\}}{\text{Max}}\ PV = p(t)f(t)e^{-rt} - C$,

where p(t) is the stumpage price (weighted by the structure of a cubic meter of timber) as a function of harvest age t, f(t) is the yield function, and C is the establishment cost. The first-order condition

(A9.6) $p'(t)f(t) + p(t)f'(t) = rp(t)f(t)$

requires that the value increment equals the opportunity cost of the growing stock.

Dividing through by p(t)f(t), the relative rate of value increment must equal the discount rate. (To simplify, a single rotation is formally considered. An infinite time horizon would imply $[p'(t)f(t) + p(t)f'(t)]/[p(t)f(t) - C] = r/(1 - e^{-rt})$, where both sides are greater compared to $[p'(t)f(t) + p(t)f'(t)]/p(t)f(t) = r$. However, the omitted effects – from the reforestation cost and the land rent

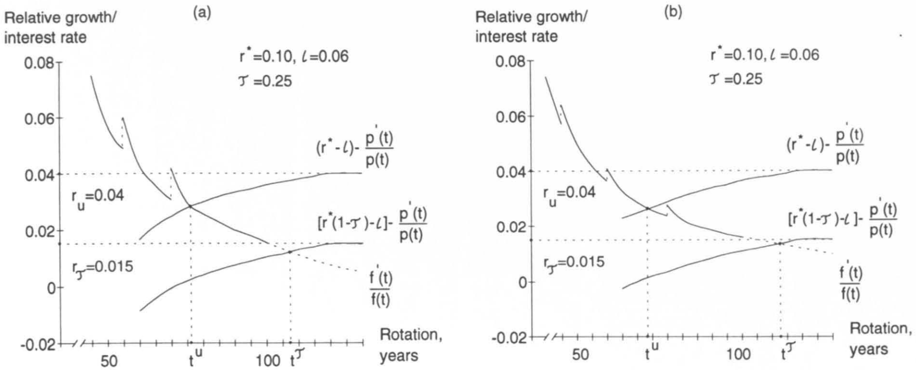

Fig. A9.1. The effect of capital income taxation on the optimal rotation. (a) Norway spruce, K24:10 (Vuokila & Väliaho 1980). (b) Scots pine, M24:5 (Vuokila & Väliaho 1980).

factor – tend to cancel each other). Rearranging,

$$\text{(A9.7)}\quad \frac{f'(t)}{f(t)} = r - \frac{p'(t)}{p(t)}$$

shows that the percentage rate of value increment at the optimum must equal the real interest rate *minus* the percentage rate of price change per year of stand age (the latter depends on the shift of pulpwood stems to sawlogs, the price ratio between pulpwood and sawlogs, and on the impact of tree diameter on the unit value of sawlogs). For numerical examples, the following data and assumptions are employed.

(1) The rates of nominal interest and inflation are 10% and 6%, respectively, so that the *undistorted* real interest rate $r_u = r^* - \iota$ is 4%. As this is a reasonable guess for the social discount rate (Appendix 5), the optimal rotation at 4% is taken to represent the socially optimal harvest age. With a capital income tax at 25%, the forest owner's effective *after-tax* real interest rate $r_\tau = r^*(1 - \tau) - \iota$ will be 1.5%.

(2) For data on the volume growth per cent, the growth series M24:5 and K24:10 for Scots pine and Norway spruce in Vuokila & Väliaho (1980) are used. The rate of price change per year of stand age is approximated by using (a) the ratio of value and volume growth per cents as a function of mean diameter (Nyyssönen & Ojansuu 1982, pulpwood/sawlog price ratio 50:100) and (b) the development of mean diameter in Vuokila (1983).

As a result of the capital income tax, the undistorted $r_u = r^* - \iota$ in the analytic solution is replaced by $r_\tau = r^*(1 - \tau) - \iota$. Thus, the distortion from capital income taxation in this case is represented by the difference of optimal harvest ages at discount rates of 4% vs. 1.5%, with all other things equal. The results are shown in Figs. A9.1(a) and A9.1(b). For spruce (K24:10), the optimal harvest age increases from about 75 years to around 108 years. For pine (M24:5), the respective change is even larger, from about 70 years till 110–115 years. Note that the impact will not change if τ is also applied to net timber revenues, since $(1 - \tau)$PV is maximized at the same point as PV.

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