An Environmental Accountant's Dilemma: Are Stumpage Prices Reliable Indicators of Resource Scarcity? [♦]

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Abstract

In resource accounting, shadow prices of natural resources and environmental effects should be used as the social marginal value of goods. Since it is difficult to measure shadow prices in practice, market prices are often used as proxies for shadow prices. A prerequisite for the use of these proxies is that there is an established relationship between size of the natural resource stock of interest and its market price. We have unique data sets on physical timber inventories in Finland and Sweden to analyze whether changes in stumpage prices have actually reflected changes in the stocks during the past seventy years. Cointegration and unit root tests are used for analyzing whether changes in market stumpage prices have reflected changes in physical timber stocks in Finland and Sweden during the past seventy years. The results indicate that no long-term equilibrium relationships exist between the timber prices and stocks.

Key words: stumpage prices, timber stocks, renewable resources, cointegration.

JEL classification: C32, Q23

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1. Introduction

Environmental accounting in practice is an ambitious pursuit. Economists agree in theory that in order to make the net national product (NNP) reflect the use of natural resources and environmental capital, these valuable stocks should be incorporated into national accounts.[1] The problem is that neither ecology-economy feedback mechanisms nor their monetary values are easy to recover. Even though many environmental and natural resource stocks provide flows of various services that are necessary for the functioning of an economy, these services are often underpriced, if not unpriced altogether. An accountant faces considerable challenges when trying to put appropriate "price tags" on such services in order to revise the NNP correctly. In practice, it has proved easiest to start green accounting from a valuation of natural resource assets that have some form of direct or indirect market prices. For example, the value of the natural growth of forests has been derived using stumpage prices which reflect the raw material value of forests, but the value of the capacity of forests to absorb greenhouse gases has often been ignored because of the various uncertainties regarding climate change and its environmental effects.

According to the theory of natural resources, there should be a relationship between the physical size (volume) of a valuable resource stock and its shadow price (rent) over time. The scarcity of a resource should be reflected in shadow prices: when a renewable resource stock decreases, the corresponding shadow price of the stock increases. Unfortunately, there are at least two practical problems related to the optimal shadow pricing of (net changes in) natural resource assets.

First, since we normally do not have observations on the shadow prices of natural resources, market prices have to be used as proxies for resource rents in accounting. This shortcut may be problematic, however, if there is reason to suspect that the market prices are not optimal from the point of view of natural resource management. Externalities and lack of property rights often lead to pricing failures. Second, the theory of natural resources indicates that not only physical changes in the stock of capital but also changes reflected in the shadow price of a natural capital stock are of importance (Asheim (2000)). Consequently, the total monetary value of a resource stock derived by using correct shadow prices does not necessarily reflect *physical* change, since the 'volume effect'

[1] The theoretical foundations of this type of extended welfare accounting lie in the work of Weitzman (1976), which was later elaborated by Solow (1986). Repetto et al. (1989) and Hultkrantz (1992) are examples of empirical studies in which traditional national accounts have been adjusted for environmental effects. The United Nations' Handbook of Integrated Environmental and Economic Accounting from 1993 is under revision and some countries have made certain progress in natural resource and environmental accounting in practice.

and ‘rent (price) effect’ may cancel each other out. In the resource accounting literature, this problem has been acknowledged as an argument against using monetary indicators of sustainability (e.g., Hanley et al (1999), p. 59). Even if market prices were optimal from a social point of view, we still would have a problem when using these prices in accounting because important information about physical resource scarcity can be lost in the aggregation.

Considerable progress has been made toward resolving basic theoretical issues of green accounting, and there is a demand for applied theory which should be tested in different country contexts (Vincent, 2000). Up to date, forests are the most extensively studied renewable resource in green accounting framework (see, e.g., Vincent and Hartwick (1997) and Vincent (1999)). We focus on forests to investigate whether changes in physical resource stock are in fact reflected in market prices. We use annual data on timber stocks and stumpage prices in Finland and Sweden from the last seventy years. Forestry has been important for economic development in both of these countries, and a systematic resource inventory was started already in the beginning of the 20th century. The stumpage prices should capture the raw material value of forest biomass, or the resource rent, relatively well, because the property rights have been clearly defined. In addition, data sets spanning such a long time period potentially reflect the changes in the natural resource dependency of the economies. During the past ten years, information and communication technology – with companies such as Nokia and Ericsson the flagships – has challenged the position of the forest sector. In Finland, for example, the electronic equipment industry, built largely upon human capital investments, increased its share of total-economy value-added from less than 2 percent in 1990 to more than 6 percent in 1999, whereas forestry and the forest industries remained at their 8 percent share of the total GDP (Elmeskov and Scarpetta (2000), Finnish Statistical Yearbook of Forestry 1999). Our approach may be visionary also from the point of view of economic history in attempts to understand the nature of the concerns and the state of restructuring processes in today’s developing world, which is dependent on raw material exports. Since time series as long as those used here are rather unique in forestry, it is interesting as such to analyze the data using econometric methods.

Recent empirical analyses using modern time series econometric methods to study natural resource rents are Berck and Roberts (1996) and Ahrens and Sharma (1997), who tested price trends of certain nonrenewable natural resources. Similarly, the work of Hotelling (1931) has been applied to the mining of the renewable forest resources by Barnett and Morse (1963), Brown and Field (1978), Lyon (1981), and more recently Hultkrantz (1995) and Seroa da Motta and Ferraz do

Amaral (2000), who have analyzed time paths of timber prices and depreciation of stocks both theoretically and empirically. None of these studies include resource stocks in the analyses. Nevertheless, as Hyde and Amacher (1996) note, timber prices are believed to reflect the development of resource stocks over time.

Of course, empirical modeling of the demand for and supply of roundwood has been an important research topic in forest economics for a long time. There are numerous studies indicating that many factors, not only prices, affect forest owners' harvesting and selling behavior (e.g. Kuuluvainen (1989), Kuuluvainen et al. (1996)). In a similar way, the demand for and price of roundwood are affected by business cycles in the forest products industry (e.g. Brännlund et al. (1985), Newman (1987), Hetemäki and Kuuluvainen (1992), Toppinen (1998)). Finnish and Swedish timber stocks comprise one third of the inventories in the European Union, but we are well aware that the stumpage prices of roundwood as raw material for the forest products industry are basically determined on the international markets. Most likely they are derived from the prices of wood-based final products independently of the sizes of the regional timber inventories. Yet, this does not make it less interesting to study our main point, that is, whether stumpage prices reflect the size of forest reserves. The issue should be especially important now that forest reserves are included as wealth, or assets, among other capital stocks in European national accounts and their monetary valuation is a relevant issue (Commission of the European Communities (1996)).

The paper is organized as follows. In section 2, we first derive a theoretically consistent and socially optimally valued consumption for an economy, or “green” national income, measured in the Hicksian sense. Section 3 then treats empirical estimation, methods and data. Results are presented in section 4. This is followed by the discussion in section 5 and by conclusions in section 6.

2. The model

When adjusting the national accounts for the use of natural resources, it is recommended that, if possible, market prices should be used in the first place in the valuation. For example, it is stated that in valuation of European forests “The stumpage price is the price that should be used for the valuation of standing timber” (Eurostat, 2000). This is in line with the European System of

Accounts (ESA) which privileges market prices as ESA's basic reference for valuation (ESA §1.51; Commission of the European Communities, 1996).

To show rigorously why the use of market prices (stumpage prices) as proxies for shadow prices of renewable resource stocks (forests) has important consequences for welfare interpretations of extended national green accounts, we use a simple dynamic model. We consider forests as a source of renewable, but potentially depletable, timber harvested for use as raw material. By focusing on the timber scarcity aspect, we consciously leave other important aspects such as environmental services provided by forests out from the model. In fact, we develop a forestry accounting framework for annual timber production which is allocated to annual consumption (harvest) and annual investment (change in forest assets).

Let us consider a model of a resource extracting sector harvesting a renewable resource stock, *V(t)*. The stock is increased by natural growth[2], *F(V(t))*, and depleted as the resource is used, *h(t)*. We assume that the sector is a price taker in both the input and output markets, and the output price is denoted by *p(t)* and the harvesting costs by *c(t)*. The net revenue from harvests, *[p(t)-c(t)]·h(t)*, is discounted over time by a constant interest rate $\delta > 0$. Since the natural resource stocks are of particular importance when constructing environmental accounts, the economy's objective is to maximize the discounted integral of profit *subject to the resource constraint dV(t)/dt = F(V(t)) – h(t)*, which captures the dynamics of the stock variable. The current value Hamiltonian can be written as *H(t) =[p(t)-c(t)]·h(t) + j (t) [F(V(t)) - h(t)]*, where the current value shadow price of the resource stock is *j (t)*. The optimal infinite time solution must satisfy the following conditions:

(1) $\partial H(t)/\partial h(t) = p(t) - c(t) - \varphi(t) = 0$

(2) $d\varphi(t)/dt = \varphi(t)[\delta - dF(V(t))/dV(t)]$

(3) $dV(t)/dt = F(V(t)) - h(t)$

Equation (1) is a social optimality condition; it says that the marginal profit from harvesting one unit of the resource, *(p(t)-c(t))*, must equal the current value shadow price of a unit of the resource in situ.

[2] Our analysis is limited to a resource stock of a size for which the following assumptions on natural growth hold true: $F_V>0$, $F_{VV}<0$.

In green accounting, the current value Hamiltonian has been interpreted as a theoretical basis for an economy's net domestic product (NDP). Weitzman (1976) showed that the Hamiltonian as comprehensive current NDP is a stationary equivalent of future consumption, or “a flow-equivalent proxy for future welfare”. Weitzman's original utility function was linear $U(C(t)) = C(t)$, and this formulation has also been used by Solow (1986) who was explicitly interested in a renewable resource stock with state equation $dV(t)/dt=F(V(t))-h(t)$. Our model is in fact the Solow model. Weitzman (2000) has lately elaborated further on the linearized Hamiltonian as comprehensive NDP in a green accounting context leading to a conclusion that the welfare interpretation of the Hamiltonian is a static equivalent constant utility level. See, e.g., Heal and Kriström (2001).[3]

In our forestry sector accounting framework, when the resource use is optimal according to (1), the Hamiltonian yields NDP $= j\,F(V)$, which is equal to nature’s annual production. Growth of the resource stock is then valued by its shadow price, which is the current opportunity cost of the standing forest stock. The shadow price captures the value of future harvesting benefits and determines the optimal conservation of stock. In case of timber resources, the most obvious proxy for the shadow price is the stumpage price which, according to the derivation above, should react to different stocks levels in order to signal about scarcity. Given the welfare interpretation assigned to the Hamiltonian in the green accounting literature, it is important to test whether there is a relationship between stumpage prices and national forest stocks.

A steady state and dynamics on the path towards a steady state

By definition, both the stock and its shadow price $(V(t), j(t))$ are constant in a steady state, and the NDP becomes $[p(t)-c(t)] \times h(t)$. However, if the economy is not in a steady state initially, the shadow prices and, accordingly, the accounting prices will change over time. To illustrate this, let us consider the current value Hamiltonian, which is $H(t) = j(t)[F(V(t))]$ (on the optimal path $p(t)-c(t)= j$). If the interest rate exceeds the marginal growth rate of the resource stock, $\delta > dF(V(t))/dV(t)$, it is viable to invest less in the renewable resource stock which will, as a result of increased consumption, decrease. Meanwhile, the shadow price of the resource stock will increase, although at a slower rate, as can be seen from equation (2). The social scarcity price of the resource

[3] The Hamiltonian-based Hicksian measure of income has been actively discussed in the context of green accounting in recent years. See Mäler (1991) and Hartwick (1990), which are based on Weitzman (1976). See also Aronsson and Löfgren (1999), Asheim (1997), and Dasgupta et al. (1994).

will increase until the resource growth has reached a steady-state level corresponding to the interest rate such that $dF(V(t))/dV(t) = d$.

In other words, as is also illustrated in Figure 1, given the functional form of the resource growth, $F(V(t))$, and the equation of motion for the co-state variable, $dj(t)/dt = j(t)(d - dF(V(t)/dV(t))$, if $dF(V(t))/dV(t) < d$ initially, it follows that $dV(t)/dt<0$ and $dj(t)/dt>0$. Evidently, the socially optimal accounting prices, $j(t)$, will increase on the path towards a steady state because the resource base is decreasing and the goods produced become more valuable socially. It should be noted that the increase in shadow price reflects change in the productivity of the asset, or the interest, i.e., the growth rate. The productivity change differs from market variations in asset prices, which do not necessarily reflect changes in shadow prices.

It is interesting to see what *the Hamiltonian*, as a measure of welfare, tells us about the change in welfare when an economy is moving towards a steady state. In the case described above, when the resource stock is decreasing on the path towards a steady state, resource growth slows down and the shadow price of the (resource) stock increases. Depending on the relative magnitude of stock growth and shadow price, the Hamiltonian may be *either* increasing *or* decreasing, since $j_{ss}(t) > j_o(t)$, and $F_{ss}(t) < F_o(t)$ and therefore $H_{ss}(t) - H_o(t) = (j_{ss}(t)F(V_{ss}(t)) - j_o(t)F(V_o(t))$, which can be either positive or negative.[4] The Hamiltonian thus conceals some of the information about environmental changes needed for policy planning. When an economy is moving towards a steady state, the Hamiltonian will not necessarily provide any indication of the change of physical volumes of resource stocks, even if correct, or optimal shadow prices are used in accounting. One may well ask whether the economy is in fact on an optimal path, but we will not pursue this question further here (see, e.g., Dasgupta and Mäler (1999)). Our focus is an econometric analysis of the relationship between rents and resource stocks.

3. Econometric issues and data

For relationships including non-stationary time series data, statistical inference based on conventional *t* and *F* tests is invalid and the results obtained may be spurious. A time series is denoted *I(0)* when it is already stationary in levels and non-stationary and integrated of order *d*

[4] Subscript *ss* refers to steady state and *o* to initial value, e.g., H_{ss} denotes the Hamiltonian at a steady state and so forth.

(I(d)) when it must be differenced d times in order to achieve (weak covariance) stationarity (see, e.g., Banerjee et al. (1993), Maddala and Kim (1998)). Cointegration is essentially based on the idea that there may be co-movement between trending economic time series such that there is a common equilibrium relation which the time series have a tendency to revert to in the long run. In the short run, there can be divergence from equilibrium. Thus, even if certain time series themselves are non-stationary, a linear combination of them may exist that is stationary. In the present case, we are interested in testing whether there is an equilibrium relation in the long run between annual timber price and timber stock series over the period 1926 to 1998.

Johansen's (Johansen (1988), (1995)) full information maximum likelihood method has become by far the most popular method in empirical estimation of cointegration relations. The method is efficient because of the incorporation of both long- and short-run effects (i.e. adjustment to equilibrium) in the empirical model structure. In this study, the cointegration rank is determined by estimating a two-dimensional VAR(k) model (see Johansen (1995), p. 11):

(4) $$x_t = A_1 x_{t-1} + \ldots + A_k x_{t-k} + m + e_t, \quad t = 1,\ldots,T,$$

where x_t is a vector of variables, here the timber stocks and timber prices in Finland or Sweden. In (4) m is a vector of constant terms, k is the lag length (k = 1,...,N) and e_t is a vector of error terms assumed to be NID(0,Ω). Equation (4) is re-parameterized in error-correction form (see Johansen (1995), p. 89) as:

(5) $$Dx_t = G_1 Dx_{t-1} +, \ldots, + G_{k-1} Dx_{t-k+1} + Px_{t-k} + m + e_t, \quad t=1,\ldots,T,$$

where Dx_t is an I(0) vector. In (5) the constant term, m, can be restricted to cointegration space in the estimation if it is assumed that there is no linear drift in x. $\Gamma_1,\ldots,\Gamma_{k-1}$ and $\Pi = - I + \Pi_1 +,\ldots,+ \Pi_k$ are coefficient matrices. Γ describes the short-term dynamics of the process and Π is the matrix of long-run coefficients, which can be decomposed into a matrix of loading vectors, α, and a matrix of cointegrating vectors, β, such that $\Pi=\alpha\beta'$. The cointegration vectors define the stationary linear combinations (if there are any) of the variables in x_t. The rank test in the Johansen procedure is used to determine whether there is a cointegration vector, β, in this bivariate case, i.e. rank (Π) = r

= 1. A likelihood ratio based trace test for testing cointegration rank, r, where the null hypothesis H_0 : r = 0 against $1 \leq r \leq 2$.

A unique set of time series data for Finnish timber prices covering the period from 1911 to 1998 was available in this analysis. Nominal, annual coniferous sawlog stumpage prices were deflated by the Finnish wholesale price index. The Finnish timber stock data were constructed by adding net growth to the previous stock level annually[5]. As some inconsistencies were observed in the earliest Finnish timber stock data, only data starting from 1938 were used in the analysis. As a consistency check, these observations were compared to statistics collected in the context of regular timber inventories, which are available for approximately every 8 to 10 years.

We used the Swedish timber stock data for the period 1926 to 1998, but coherent Swedish stumpage price series were more difficult to find. Like Hultkrantz (1995), we used a number of different data sources in order to obtain a price time series that covers the whole period 1926-1998. Streyffert (1960) reports stumpage prices for public forests covering the period 1926-1958, which are complemented by official statistics on stumpage sales on public and private land for the later period 1955-1998. Thus, the chained time series for the period 1926-1998 is based on sales on public lands for the years 1926-1951, on both private and public lands for the years 1952-1972 (where we employ the mean of these prices), and on private land only for the years 1973-1998. Although the data is based on somewhat varying samples, we shall henceforth assume that this time series represents an accurate estimate of the market value of standing timber for the years 1926-1998. Lacking a common Swedish deflator for the time span under consideration, we have used the Cost of Living Index for the years 1926-1935, the Consumption Price Index for the period 1935-1949 and the Consumer Price Index for the period 1949-1998.[6]

The data plotted in Figure 2 show that inventories of timber in both countries increased steadily over the period studied. Real stumpage prices show strong business cycle fluctuations and fitted trends in stumpage prices show about 1% increase per annum in both countries. Logarithms of the time series were used in the econometric analyses.

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[5] The term net growth is here consistently defined as growing stock increment minus drain (losses in growing stock due to felling, silvicultural measures and natural mortality).

[6] A more detailed description of the data sets and sources is available from the authors.

4. Results

Prior to cointegration analysis, Augmented Dickey Fuller (ADF) (Dickey and Fuller 1979) unit tests were performed for individual time series.[7] Various lags of differenced dependent variables were used to remove autocorrelation from the residuals of test equations by applying the strategy that selects the highest lag with a significant t-value. The results in Table 1 indicate that the null hypothesis of non-stationarity could not be rejected for inventory series in Sweden or Finland, although it could be rejected for their first differences at the 1% and 5% level, respectively. For stumpage price in Finland, non-stationarity could be rejected at the 5% level. For Swedish stumpage price, the null-hypothesis of non-stationarity was not rejected.

Table 1. ADF-test results for timber price and inventory series. T indicates the inclusion of a trend in test equation and k shows the number of lagged differences in the equation.

	Levels of time series	1st difference of time series
Sweden (1926-98):		
Timber inventory	-2.31 (T, k=2)	-4.17** (k=1)
Stumpage price	-1.91 (k=0)	-7.90** (k=0)
Finland (1938-98):		
Timber inventory	-2.07 (T, k=1)	-1,89* (k=1)
Stumpage price	-3.05* (k=0)	-8.35** (k=0)

*(**) denotes the rejection of null hypothesis of non-stationarity at 5 % (1 %) level.

The testing points out that since Finnish stumpage prices can be regarded as stationary at the 5 % level no cointegration can exist. Therefore, we have to be extremely careful when proceeding to test for cointegration between the Finnish data. In contrast, the analysis suggests clearly that Swedish timber price and inventory are integrated of order one, and thus, it is important to test for possible cointegration between the series.

Using Johansen's cointegration method, a two-variable VAR-model was estimated for each country. Since inventory data for both countries are trending, a specification allowing for an unrestricted constant in cointegration regression was chosen. As the method is fairly sensitive to the

[7] The empirical analysis was performed using PcFiml 9.0.

number of lags used in the analysis, different models were compared using both residual tests and a procedure incorporating sequential decreases in the number of lags was applied in choosing a suitable model. Using these criteria, a two-lag model was found to be sufficient to remove residual price autocorrelation in the Swedish model, while a model with three lags proved more suitable for Finland. The chosen VAR-models were tested using standard procedure in PcFiml to be acceptable statistical formulations regarding residual autocorrelation, normality and heteroscedasticity (results available from authors upon request).

The existence of long-run equilibrium relationships between timber price and inventory were tested using the Johansen's trace test, and the results are reported in Table 2. For Sweden, no co-integration could be detected irrespective of the different model specifications. It can be concluded that, in the long run, no tendency for timber prices and inventories to reach a steady state equilibrium was found for Sweden.

Table 2. Results from Johansen's tests for cointegration rank, r, between timber price and inventory. The null hypothesis is no cointegration.

	Cointegration rank	
	r=0	*r£1*
Sweden (1926-98):		
Eigenvalues	0.15	0.00
Trace test-value	11.33	0.03
95 % critical value	15.4	3.8
Finland (1938-98):		
Eigenvalues	0.16	0.01
Trace-test value	10.89	0.77
95 % critical value	15.4	3.8

For Finland, a three-lag model was found to be suitable, although the two-lag model was rejected only at the 6 % level. As reported in Table 2, no cointegration could be detected for Finland either.

However, in the Finnish time series there is an interesting period starting in the mid 1950s when the timber stock decreases as can be seen from the data plot for Finland in Figure 2. By that time the Finnish economy had begun recovering properly from the war years, and raw material use in the forest industry was increasing rapidly. Annual harvesting exceeded the natural growth of forests, and for several years the net growth of the forest stock was negative. One would expect that market prices would have reacted to the intense harvests and the decline of the stock. If the prices did not react to increased harvests, as our tests above seem to indicate, one explanation could be that a relatively large timber stock as a variable does not capture such net changes in the stock, or relative scarcity, quickly enough.

Due to the above concerns, we went on to test whether there would be cointegration between Finnish stumpage prices and the *net growth* of forests. The idea was that the timber prices would perhaps be more sensitive to the negative net growth figures than only occasionally declining, but constantly positive, timber stock figures. Finnish data on the annual net growth of forests are available from 1911 (see Figure 3). A testing procedure similar to that used above with timber stocks was applied. The results of Johansen's cointegration test also failed to support the hypothesis that cointegration existed between market prices and the net growth of forest stock in Finland (Table 3). On the contrary, Johansen's trace test showed that the number of stationary equilibrium relationships in the system was two, which indicates that both net growth and stumpage price are in fact stationary and thus that *no* long-run cointegrating relationship can exist.[8]

Table 3. Results from Johansen's tests for cointegration rank, r, between stumpage price and net growth of forests in Finland.

	Cointegration rank	
	r=0	*r£1*
Finland (1911-98):		
Eigenvalues	0.15	0.08
Trace-test value	21.03**	7.03**
95 % critical value	15.4	3.8

The null hypothesis is no cointegration and * (**) denotes rejection of hypothesis at 5 (1) % level.

The test result of no cointegration for the Finnish net growth model was more definite than that for the timber stock. Hence, the overall results of our analysis of the Finnish and Swedish forestry data do not support the hypothesis that market prices reflect the physical development of forest stocks. It must be borne in mind that sustainable use of natural resources is often related to the country's phase of economic development. During a ten-year period from the mid 1950s onwards, harvests exceeded the growth of Finnish forests annually because of extensive increase in raw material use in the forest products industry. However, it is difficult to say whether market prices reacted to the intense use of forest resources or to business cycles, and the econometric analysis does not give evidence of a long-run cointegrating relationship between stock and prices. Lacking equilibrium relationship would be unfortunate from a social point of view, if sustainable use of resources were a concern in managing resources. This may be even more worrisome if this is true also for those economies that are today in their early stage of economic development and dependent on natural resource assets.

Before drawing conclusions, however, an important element regarding the assumptions and implications of the theoretical model and the empirical analysis needs to be discussed. A natural extension to the analysis presented above is to consider the nature of price formation on the roundwood markets more specifically. When roundwood is traded internationally, and if the markets are integrated so that the equilibrium stumpage prices are determined on the international markets, *the size of a forest stock in a single country* is perhaps too restrictive an explanatory supply side factor. In the present case, proven cointegration between Finnish and Swedish stumpage prices would be an indication of internationally functioning roundwood markets.[9] Mere visual examination of Figure 4 does not seem to rule out the possibility of cointegration between real prices in the two countries. The test results indicate (not reported, but available from authors upon request), however, that these two prices are not cointegrated, even when the possibility of a deterministic trend in real prices is taken into account. This indicates that international arbitrage does not exist to a sufficiently high degree in these markets to allow aggregation over countries, and, therefore, it is necessary to analyze price-stock relationships empirically on a country-by-country basis, as was done here.

5. Reservations about the analysis and discussion

Our empirical analysis suggests that market prices for timber are not cointegrated with the size of forest resource stocks in a theoretically consistent way. Yet, this empirical complication is often

[8] No statistical relationship between these two variables was found in a conventional OLS regression either.
[9] It could be argued that also stumpage prices in the other forestry countries are needed to test cointegration of roundwood markets. However, previous studies (e.g. Thorsen 1998, Toivonen et al. 2000) have shown that even the Nordic countries differ from the other European countries, possibly due to different market practices, high transportation costs or the use of different wood species. Therefore, it is highly unlikely that prices in countries *outside* Europe (e.g. in the tropical regions or in the North America) would directly affect Swedish or Finnish prices except through the export markets of the forest industry products.

assumed away in theoretical social planner models, and national accountants do not "press welfare interpretations of calculated GDP and NNP too hard" by making calculations at *observed* prices and quantities (see Hartwick (1990), p. 296). Perhaps this is a concern for environmental accountants if the principal purpose of developing resource accounting is to provide information for environmental policy decisions. Of course, as researchers our concern is what can be wrong in our analysis, and some potential caveats are discussed next.

Data and measurement

Some of our reservations derive from data and measurement. The total physical stock represents a mix of all age classes, species and qualities, whereas stumpage prices reflect the raw material value of mature forest ready for final felling. Using the stumpage price for valuation will clearly lead to an overestimate of the total timber value of forest reserves including seedling and thinning stands. For accounting purposes, a prerequisite for stumpage prices to reflect, or to react to the scarcity of forest reserves is then that the share of mature forest stands has remained approximately constant over time.

In our data set, an important consideration is that the regional distribution between old and young forests has changed since the beginning of the century. For example, in northern Sweden the share of forest older than 120 years has decreased from 33% to 23% in the years 1926-1985, while in southern Sweden the share of forest older than 80 years increased from 7% to 20% during the same period (Nilsson (1990), p. 66). On the national level, the share of old forests (over 80 years old) is still approximately the same today as in 1926 (Riksskogstaxeringen 1999). A similar regional trend for old growth forests can be seen in Finland as well: a decrease from 55% to 25% in the north and an increase from 3% to 5% in the south (Metsätilastotiedote 1996). Since changes in domestic stumpage prices of sawnwood and pulpwood assortments have evolved in a similar manner over time, regional variations in the quantity of different types of timber (sawnwood/pulpwood) and species (spruce/pine/birch) do not raise concerns in our aggregated data sets.

The timber stock figures we have used also include forestland where other land uses significantly restrict timber production (military use, national parks, reserves etc.); this part of the standing stock obviously contributes to the total quantity of the stock but is not subject to market transactions. However, the bulk of these large unharvested areas are located in northern forestlands, the economic importance of which is rather limited, i.e., they account for some 5 % of the total timber stock in each country (Skogsstyrelsen (1993), p. 76; Finnish Forest Research Institute). In addition, public investments in building up forest road networks have considerably decreased the regional differences in the physical access to forest reserves and in unit costs of harvesting and transportation.

A third issue that relates to the measurement of the physical forest stock concerns the overall accuracy of the national forest inventory measurements. The Nordic countries started national forest inventories in the early 1920s, the U.S. in the early 1930s, and central and western Europe after the second world war. To date, only 22 out of 137 developing countries perform repeated inventories (FAO, 2000). In each Finnish and Swedish inventory, the national forest resources (soil, site quality, amount and quality of growing stock and growth by tree species) have been estimated using ground-based field measurements. The accuracy and precision of the estimated forest stock data from the national forest inventories are discussed and evaluated, e.g., in Li and Ranneby (1992) and Tomppo (2000). Previous studies indicate that the estimates of the Finnish and Swedish stocks used in our data set have been measured systematically and precisely over a very long period of time.[10] However, the availability and quality of data on the total aggregate stock of timber is a serious concern for countries that do not have systematic forest resource assessments. Recently, new methods for this task have been developed, including use of spaceborne and ground-based data from several sources to estimate, e.g., land use category, site quality, tree species proportions, tree stem volume by tree species, growth, leaf area index and total biomass of trees. One concern with these less expensive methods has been that they are perhaps not as accurate as field measurements.

Besides timber fuelwood has a significant economic importance for national accounts in developing countries which should be acknowledged in the measurement of the forest stock as well. In addition, we have consciously excluded from our analysis different amenities provided by the forest stock. For example, recreation services are getting increasingly important in urbanized areas in industrialized countries. Therefore, we want to stress the importance of clearly defining what the valuable resource stock is, and then finding a market price that actually captures the scarcity of this stock. When *no* market prices are related to *any* stock of forest services of interest, studies of the demand for non-market priced goods and services are required (Braden and Kolstad (1992)).

[10] Li and Ranneby (1992) report a 0.6 % coefficient of variation for the estimate of total standing volume in Sweden. A corresponding statistics of 0.7 % for the Finnish standing volume has been reported by Kuusela and Salminen (1991). For specific tree species or smaller regions, the coefficient of variation is of course larger.

Institutional setting and forestry policy

Before green accounting practitioners can use the present theory as guidance, the validity of certain assumptions behind the theoretical model must be scrutinized. The assumptions normally considered as most restrictive are: well-defined property rights, no technological change, and a constant interest rate. As mentioned above, the property rights are not a concern in Scandinavia, where a major part of the forest resources are privately owned, in contrast to the situation in many developing countries today. The other two assumptions are more relevant.

The last century has brought considerable technological progress, which certainly should be reflected in timber price changes. However, the lack of cointegration between the Finnish and Swedish stumpage prices would indicate that price development on the roundwood markets is affected by factors other than technological changes that cross national borders.

It is difficult to evaluate the importance of the non-constant interest rate in forestry. Foresters have asserted that the ultimate goal of forest management should be to maximize sustained yield, or the average output over the rotation period (Johansson and Löfgren (1985), p. 90). If this were the case, the interest rate, or opportunity cost, would not play any role in forestry, which may be an awkward notion to an economist.

Finally, optimization behavior may be distorted by government interventions. For example, when harvests exceeded annual growth in the late 1950s in Finland, the government started subsidizing investments in forestry so that the emerging scarcity of raw material for the forest industries would not be reflected in stumpage prices, at least not in its entirety. Devaluation of the exchange rate was also actively used to dampen domestic inflation and stumpage price increases (Ollonqvist (1998)). However, the forest inventory statistics at that time made it possible to discern what an increased demand for raw material by the forest industries could have led to. Systematic inventory data thus speeded up political reactions to concerns of over-harvesting.

6. Conclusions

The motivation for our analysis stemmed from the problems of valuing natural resource assets in doing resource accounting in practice. Our concern is that a corrected green NNP measure based on market prices does not necessarily serve its initial purpose of indicating changes in the “welfare of the environment”.

In previous analyses testing scarcity of natural resources empirically, the point of departure has often been the Hotelling framework of price behavior of exhaustible resources. However, no one has denied the existence of market failures or other factors which may cause the market prices of resources to deviate from true scarcity prices. Here, we have carried out an empirical analysis on renewable resources, forests in Finland and Sweden, and unique forestry time series data have allowed us to consider both resource prices and development of resource stocks simultaneously.

Our goal was to test whether market prices reflect the abundance/scarcity of a renewable natural resource. If this is not the case, we may have a serious problem if sustainable use of resources is a concern. However, if this is the case, the green accounting literature tells us that not only physical changes in the stock of capital but also changes reflected in the shadow price of a natural capital stock should be counted. When these changes move in opposite directions, we face the paradox that even though market prices might give a relatively good approximation of socially optimal shadow prices, a green NNP measure as an aggregate monetary index would not indicate anything about the physical changes of the resource stock in question.

The most conservatively formulated conclusion from our analysis is then a minimum requirement that environmental accountants should always establish a relationship between market prices and the scarcity of the resource, before using these market prices as proxies for the shadow value of the stock. Our results point to an absence of any connection between market prices for timber and the growing timber stock in Sweden or in Finland. Additional tests confirmed that there is no long-run cointegration between the net growth of timber and timber prices in Finland, either. Thus, at the highly aggregate level considered in this study, we cannot find clear support for using market stumpage prices as proxies for the shadow value of the timber capital stocks in environmentally adjusted national accounts. Nevertheless, further empirical tests and analyses are warranted, for at a more disaggregated level of data, market prices may in fact reflect more accurately the size of the stock of timber.

A closer look at historical developments reveals that forest inventories in themselves have provided important statistics. In the 1960s, several forestry investment programs were established in Finland in response to concerns of meeting increased input demand in the future. Today’s concerns are different, though. Accelerated urbanization has shifted the focus from timber production to amenities. Recreation is becoming increasingly important, and the problem is that the value of the recreational services provided by forests cannot always be expressed in cubic meters. Without further investigation it is difficult to claim that stumpage prices as such reflect the quantity or quality of non-market forest amenities. A natural follow-up question is whether the value of positive externalities provided by the renewable forest stock – if not captured by the stumpage prices – can (ever) be even proportional to the market prices. We want to stress the importance of clearly defining what the valuable resource stock is, and then finding a market price that actually captures the scarcity of this stock. Non-market valuation may still be the last resort, when we have to estimate shadow prices.

Note: Subscripts ss refer to steady state; $\varphi(0) = \varphi_o$ and $V(0)= V_o$, and $d\varphi/dt = \varphi[\delta - F_V]$.
If initially $F_V < \delta$ then $dV/dt<0$ and $d\varphi/dt>0$, and $\varphi_{ss} > \varphi_o$, and $V_{ss} < V_o$.

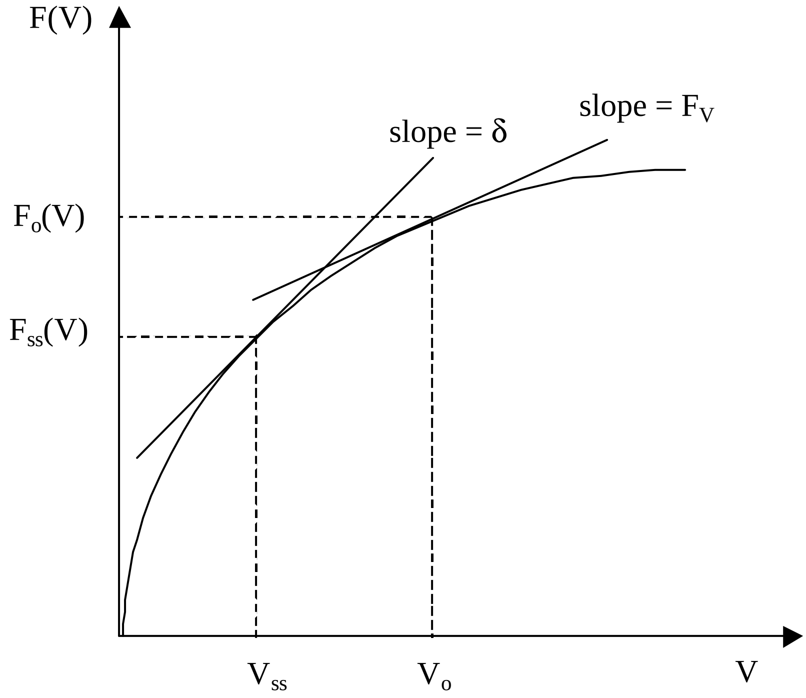

Figure 1. Changes in the values of state and co-state variables over time

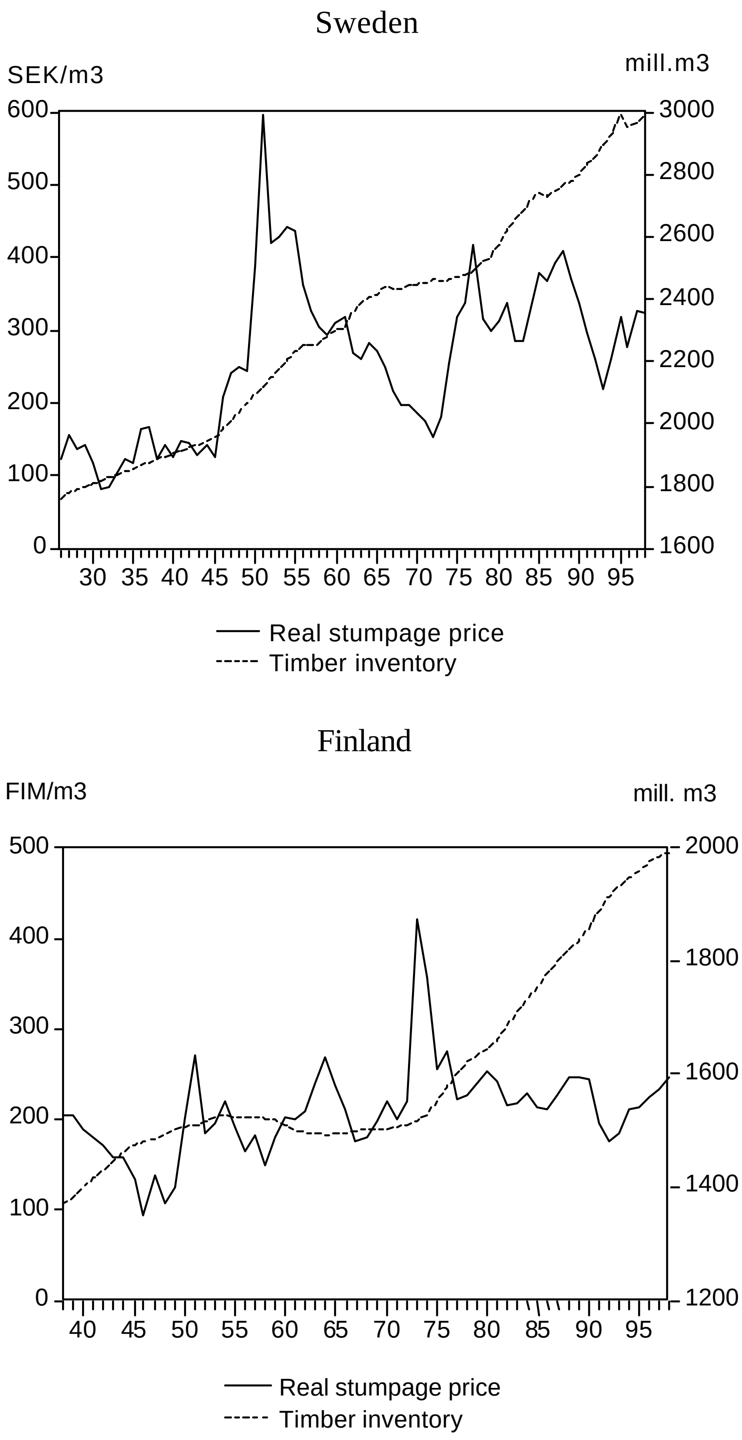

Figure 2. Timber inventory and real stumpage price in Sweden (1926-98) and Finland (1938-98).

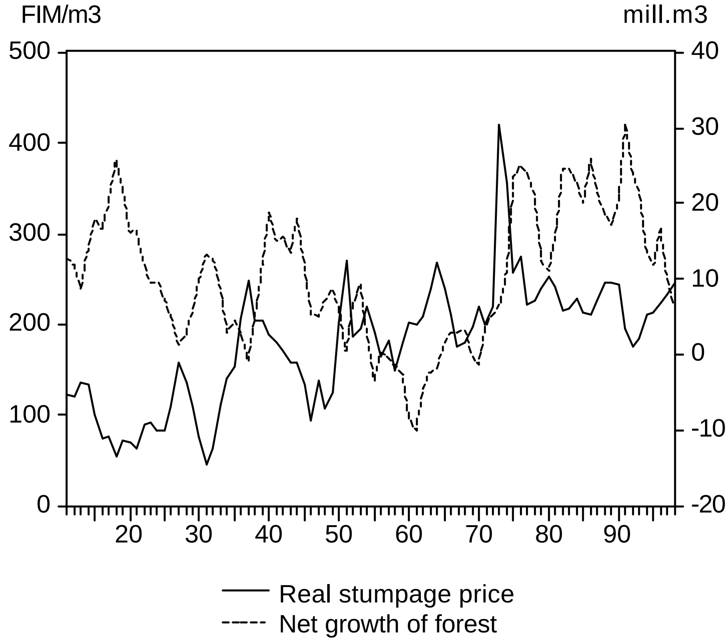

Figure 3. Real stumpage price and net growth of forest in Finland, 1911-98.

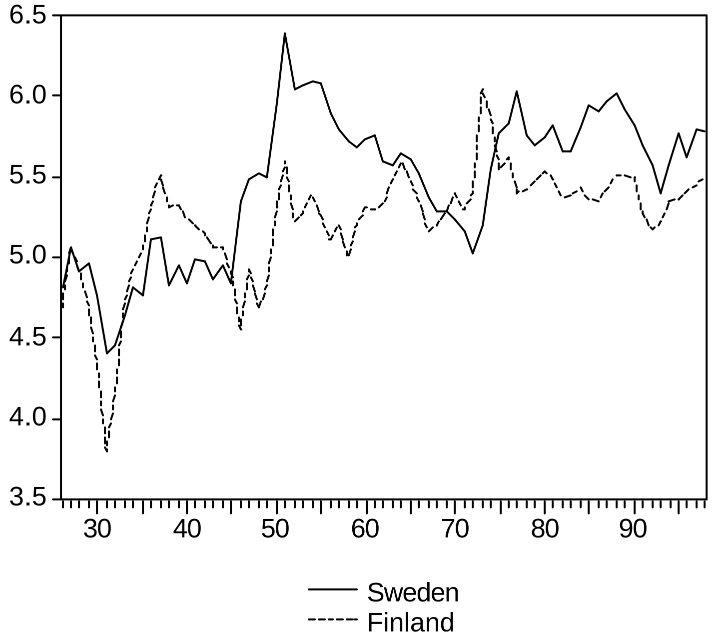

Figure 4. Real stumpage prices in Sweden and Finland, 1926-1998 (in logarithmic form).

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