Environment and Development Economics 7: 281–297 © 2002 Cambridge University Press
DOI:10.1017/S1355770X02000189 Printed in the United Kingdom

Econometric analysis of forest conservation: the Finnish experience

MIKAEL LINDEN
Department of Economics, PO Box 54 (Unioninkatu 37), FIN-00014, University of Helsinki. Email: milinden@valt.helsinki.fi

JUSSI UUSIVUORI
Department of Forest Economics, PO Box 27, FIN-00014, University of Helsinki. Email: jussi.uusivuori@helsinki.fi

ABSTRACT. This paper examines the dynamic effects of forest conservation measures. Both short-term and long-term impacts on timber markets are studied using a Finnish example. Forest conservation is interpreted as an exogenous negative shock in the standing timber growth owned by private forest owners, and its effects are retrieved through an impulse response analysis based on a dynamic demand–supply and timber stock model. The results show that timber markets are influenced by forest conservation. The conservation of forest assets reduces traded quantities and increases timber prices. These effects are of the same relative magnitude, thus leaving the annual timber-selling income of private forest owners unchanged. The results suggest that some of the negative short-run impacts of conservation on commercial timber stock will be compensated in the long run by intensified use of the remaining stock. This may to some extent reduce the ecological usefulness of the conservation policies. While the timber markets converge in the long run towards a new post-conservation state the short-term interruptions suggest that caution should be used in establishing set-asides in privately owned forestland.

Key words: Demand and supply, forest conservation, forest dynamics, impulse response analysis, land tenure, sustainable forest management.

1. Introduction

In response to increasing global, regional and national pressures, governments worldwide are revising their natural-resource policies to better address sustainability. In the case of forestry, calls for reshaped thinking and policy formation have been particularly pronounced. To address the demands, market-driven initiatives and those originating from international policies have been progressing rapidly since 1992 when Agenda 21 of the UNCTAD conference in Rio de Janeiro was released. More specifically, the biodiversity and carbon sequestration roles of forest have been laid down as the key ecological functions which define sustainable forest management. Additionally, sustainability has been anchored to the economic and social/cultural aspects of the forest sector.

The authors thank various anonymous referees for their helpful comments.

As part of the policies to achieve sustainable forest management, forest conservation has become an important instrument in many parts of the world. In fact, conservation is currently seen as an integral component of forest management, a term previously linked more narrowly to the commercial utilization of forests. At present, some 8 per cent of the world's forests belong to areas that are classified as protected (Iremonger, Ravilious, and Quinton, 1997). There exists growing pressure to bring more forests under protection worldwide. For example, international conservation groups have called for the total protection of 12 per cent of terrestrial ecosystems.

In the Northern Hemisphere, it is usually the so-called old-growth or frontier forests (Bryant, Nielsen, and Tangley, 1997) that have been targets of conservation. The aim of this type of 'total conservation' has been to preserve some of the remaining biodiversity, which the dominating secondary forests in the industrialized countries cannot usually provide. Additionally, selected biodiversity-rich segments within commercial forests have been targeted by the forest conservation policies. This way, conservation and development have been integrated at the level of forest management units.

In the South, the main concern has been to stop or slow down the decline of tropical forests. Although forest industries play only a minor direct role in causing tropical deforestation, it has been considered important to define set-aside forests—which are also known as original forests in the tropics—where industrial logging is either restricted or prohibited outright. This is all the more important when we consider the fact that forest industries do play an important indirect role in deforestation by opening up forests to small-sized subsistence dwellers who subsequently convert them into agricultural use (see van Kooten, Sedjo, and Bulte, 1999). But sustainable forest management also implies that the existing second-growth forests or so-called degraded forests under commercial use are managed so as either to guarantee their current environmental status or to improve it (Johns, 1997).

A common consequence of the conservation or sustainable forest management measures in both the industrialized and in the developing countries is that the forest-resource potential available for forest industries diminishes. Supplies of timber reserves that otherwise could be used to meet increasing future demand for wood fiber are being globally truncated (Solberg, 1996). Part of this reduction in timber from developing and developed countries can be compensated for by supplies from forest plantations, and some timber supply from protected forests may be compensated for by supply from previously unused forests (see Sedjo, 1996; Sedjo *et al.*, 1994). However, from the point of view of global wood markets, conserving forestland can be considered a permanent supply reduction.

Although the importance of the effects of these conservation policies is widely recognized by economists, analytical studies on the national, regional or global effects of forest conservation are few. Studies on the outlook for global demand for and supply of wood (Apsey and Reed, 1995; FAO, 1997a; Nilsson, 1996; Sedjo and Lyon, 1995; Solberg, 1996; Zuidema *et al.*, 1994) incorporate, in one way or other, the estimated effects of current or future forest conservation on the supply side of the used timber models. However, these studies are unable to specifically identify the conservation-induced effects on national, regional, or world timber markets. Studies that have addressed the links between markets and forest conservation include those of Sohngen, Mendelsohn, and Sedjo (1999), Sedjo *et al.* (1994), and Perez-Garcia and Lippke (1993). The first of these studies concluded that set-aside forests may lead to unexpected effects in other forests, such as increased harvesting of currently inaccessible forests. The second one found that regional 'trade-transfers' offset the initial local reduction in timber supply due to protection of forests, while the third study, by simulating the economic effects for tropical forest countries of setting aside 10 per cent of their forest inventories, suggested permanently reduced harvest levels as an outcome of forest protection. On the national level, Barbier *et al.* (1995) simulated a policy measure by Indonesia to impose sustainable management of its remaining production forests. In that study, supply restrictions were interpreted as 25 or 50 per cent increases in harvesting costs. The effects on the forest sector in Indonesia seemed to be minor.

In this study we analytically identify the price and quantity effects of forest conservation measures. Rather than estimating the cost effects of more sustainable forest management, we interpret the initial conservation measure as a negative shock in the commercially usable timber growth of private forest owners, and then follow the effects of this shock through timber supply and demand equations to identify its market impacts. Focusing on the Finnish case, we examine how public forest conservation policies affect national timber markets in the short and long run. We first estimate a dynamic timber market model—augmented with a connection to the timber stock dynamics—and then carry out an impulse-response analysis to track the conservation-induced effects on the timber prices and quantities. The long-term impacts are interpreted as the new, post-conservation state of the timber markets, provided that the estimated model is stable. Both the level of the long-term impacts and the time-path of the interim impacts are of interest; the former giving information about the total effects on prices and quantities and the latter giving information about the adjustment pattern of the effects of an external shock.

As forest protection policies together with various privatization programs and land tenure reforms—concerning also forestland—are being designed and implemented in several developing countries as well as in countries with economies in transition, it is worthwhile studying the market effects of forest protection with a case representing well-established land-tenure conditions and an enforceable environmental protection legislation. In the developing and the transition economies many institutions are not well developed. However, it is relevant from the point of institutional development to examine the national-level effects of modern environmental forest policies in developed conditions. Policy makers who are both designing land reform issues (how much of publicly owned land should be put under private tenureship, and what kind of tenureship structures should be encouraged) and land protection issues (for example, how much of planned protected areas should target land under different ownership) need to know what the wider effects of forest protection for privately owned land are. This has direct bearing on, for example, the welfare effects of environmental land protection policies.

The Finnish case is also interesting in the light of the fact that the new national forest and environmental legislation that led to the forest conservation measures is a reflection of a binding international agreement that a national government has committed itself to. Namely, the binding Helsinki inter-governmental ministerial agreement outlines, for the first time with the Montreal agreement, a common understanding of standards and measures to monitor biological and social conditions of forests at the national level (van Kooten *et al.*, 1999).

In section 2 the Finnish case is described and further motivated. In section 3 we present an economic market model with forest dynamics and the data used to estimate the econometric model. The model is estimated in section 4, while our analysis of the effects of forest conservation is presented in section 5. A discussion of the implications and limitations of the analysis is provided in section 6.

2. Finnish timber markets

Finland with its long traditions in forest management and policies, well-established land ownership and effective timber markets, provides a solid reference case for evaluating the effects of conservation on timber markets. Small family forest ownership is by far the most common type of ownership in the country: two-thirds of the forest area is under non-industrial private ownership, the rest being owned by the government and forest industries (OECD, 1997). The share of the non-industrial private forests of total timber harvesting is even larger. In recent years fairly extensive conservation acts have been enacted in the state-owned forests, putting some 20 per cent of the government forests under protection and thus out of reach of commercial utilization (Ministry of Environment, 1997).

A new forest law came into effect in 1997 in the country. Covering forests under all ownership types, this law imposes limitations on the commercial harvesting of timber. Sites and areas falling under certain ecosystem categories (for example, habitats of special importance) are protected from harvest. Estimates of the effects of these protected sites on the annual allowable cut usually vary between 5 and 15 per cent in non-industrial private forests (Mestra, 1996). This compares with volume impact estimates of 20–30 per cent made for increases in costs for temperate and boreal forests as a result of implementing sustainable forest management (Dubois, Robins, and Bass, 1995), and with even higher cost effects for tropical countries (Varangis *et al.*, 1995).

The reasons for the reduced supplies and increased costs of more sustainable forest management practices include: (i) a reduced harvest area from set-asides; (ii) lower harvesting yields, and (iii) additional harvesting costs (Baharuddin and Simula, 1996). Exact estimates are difficult to arrive at because of uncertainties about the extent and occurrence of the protected sites and ecosystems in forests. However, the effects of the conservation measures on the physical timber supply potential of the country will be substantial. In this study, we examine how large the potential economic effects of conservation might be in terms of prices and quantities. More specifically, we address the question of what, given an initial equilibrium in the timber markets, will happen to the volumes and prices on the market in the case of an exogenous shock imposed on the markets by forest conservation.

3. An econometric analysis of conservation

Background

In order to estimate the impact of forest conservation, we need an economic model to describe the Finnish timber markets. Various approaches have been used in the theoretical and empirical literature to model timber markets (for example, Kuuluvainen, Karppinen, and Ovaskainen,1996; Johansson and Löfgren, 1985; Bergman and Brännlund, 1993). However, there are no explicit models that include conservation and its timber market and stock effects. In a competitive model, forest conservation is the form of market regulation performed by state agencies. More precisely, timber stock and market supply are constrained. Naturally, less timber is supplied at a given price level. With prevailing demand, the market price of timber has to increase, but, if sellers have other timber sources that compensate for conserved stocks, a price increase will not necessarily take place, or it will be smaller than in cases where there are no compensatory resources.

The empirical economic work on timber markets has perhaps paid less attention to testing structural market model alternatives than to the construction of statistically satisfactory models (see Hetemäki and Kuuluvainen, 1991; Brännlund, Johansson, and Löfgren, 1985; Aronsson, 1990). In the conservation case analyzed here a structural approach is needed to reveal the demand and supply consequences of conservation. The suggested model is a simple dynamic structural model of timber markets that incorporates the stock adjustment effects on supply. Based on testing with different specifications, we present the following model:

$$\begin{aligned} \text{Demand equation: } Q_t &= \alpha_0 + \alpha_1 Q_{t-1} + \alpha_2 P_t \\ \text{Supply equation: } P_t &= \beta_0 + \beta_1 \mathrm{P}_{t-1} + \beta_2 \Delta g_t + \beta_3 r_t \qquad (1) \\ \text{Stock adjustment: } \Delta g_t &= c_0 + c_1 \Delta g_{t-1} + c_2 Q_t \end{aligned}$$

where Q_t is the quantity of timber demanded by the market and P_t is the supply price level at time t. Δg_t is the change in yearly natural increment of private timber stocks. These are the endogenous variables of the system. The only exogenous variable in the system is the real interest rate r_t. All the lagged variables are predetermined variables that support the adjustment to a long-run market state.

The demand equation is the most elementary one. Economic theory implies that $0 < \alpha_1 < 1$ and $\alpha_2 < 0$. The supply equation incorporates the timber quantity effects on market price in the form of the change in the timber stock increment. The market quantity Q_t is not an explanatory variable in the supply equation. However, in a competitive model it has an indirect effect on the supply price because Q_t determines the change of stock increase (see the stock adjustment equation). If the demand Q_t increases, then it has a direct negative effect on the stock increment ($c_2 < 0$). The sign of β_2 on Δg_t in the supply equation must be negative ($\beta_2 < 0$). However, an act of conservation directly reduces Δg_t at a given level of the market Q_t. The supply equation will shift upward leading to a lower market quantity with a higher price level. Thus conservation (that is lower Δg_t) and increased demand raise market price.

The feature of the model, that it is the change of the annual increment in privately held forests that forms the forest dynamics part of the specification, rather than timber stock or the increment, warrants some discussion. The underlying reason for this lies in the time-series properties of the different stock variables. The timber stock variable exhibited an integration of order 2, while the annual increment series was integrated of order 1. However, the first difference of the annual increment series formed a stationary series, and was consistent with the other series in this respect. A regression model consisting of $I(0)$ and $I(1)$ or I(2) variables forms an unbalanced model that involves statistical estimation and inference problems.

Note that real interest rate effects on supply price are also negative ($\beta_3 < 0$). The supply curve will adjust outwards in order to restore timber owners permanent income levels with increased selling as they face higher bank loan interest rates. The adjustment condition $0 < \beta_1 < 1$ on P_{t-1} guarantees that supply price has a stable long-run solution.

Model (1) describes the private pulpwood markets in Finland. Other than the domestic wood purchased from the private forest owners, forest industries in Finland receive wood from their own forest, and from state forest. The timber removals from these forests have remained stable over the years. Furthermore, wood is also imported to Finland. However, it is the domestic timber markets that dominate wood procurement and price formation in Finland.

The above specification of the timber demand equation lacks some obvious structure that could be theoretically justified. For example, output prices of goods produced by the pulpwood using industries, and prices of input substitutes for domestic timber, such as the price of imported wood, could theoretically enter the demand function. However, available series on these variables did not perform well in the estimation of the model and they were omitted in order to save degrees of freedom in the model estimate. The fact that the price for imported wood did not have a significant effect on the demand of domestic pulpwood indicates that these wood components may not be substitutes for each other.

There are two important implications of the forest dynamics specification of the model.[1] First, to be able to use the change of the annual increment as the one variable where the impact of the conservation measures is felt, we need additional assumptions concerning the 'targeting' of the conservation policies. Namely, we need to assume that the set-aside forests are representative of the privately owned forests in the structure determining the growth of the forests. This means that the

[1] We owe these to an anonymous reviewer.

https://doi.org/10.1017/S1355770X02000189 Published online by Cambridge University Press

age-structure, soil properties, and annual growth rates of the conserved forests fully represent what could be called average privately owned forests in Finland. Second, a long-run solution of the specified model—as the one we are interested in the impulse response analysis—implies a situation in which the annual increment of the forests is not constant. As a long-run forest dynamics property this seems counter-intuitive. However, within the length of time series studied in this research—nearly 40 years—this property has indeed been present in Finnish forestry: largely because of intensified management of private forests, their annual increment has continuously increased. Of course, over a very long period of time, say several hundred years, ever-increasing annual increments could not characterize a long-run steady state equilibrium. Therefore, our long-run results do not describe a time-independent equilibrium, where natural forest growth equals harvesting.

Econometric specification

Model (1) can be written in the following matrix form

$$\begin{bmatrix} 1 & -\alpha_2 & 0 \\ 0 & 1 & -\beta_2 \\ -c_2 & 0 & 1 \end{bmatrix} \begin{bmatrix} Q_t \\ P_t \\ \Delta g_t \end{bmatrix} = \begin{bmatrix} \alpha_0 \\ \beta_0 \\ c_0 \end{bmatrix} + \begin{bmatrix} \alpha_1 & 0 & 0 & 0 \\ 0 & \beta_1 & 0 & \beta_3 \\ 0 & 0 & c_1 & 0 \end{bmatrix} \begin{bmatrix} Q_{t-1} \\ P_{t-1} \\ \Delta g_{t-1} \\ r_t \end{bmatrix} + \begin{bmatrix} \epsilon_t \\ \mu_t \\ \gamma_t \end{bmatrix} \quad (2)$$

or more concisely as

$$\mathbf{A}\mathbf{y}_t = \mathbf{a}_0 + \mathbf{B}\mathbf{y}_{t-1} + \mathbf{C}\mathbf{X}_t + \mathbf{v}_t \quad (3)$$

By multiplying this with $\mathbf{A}^{-1}$ we obtain the *reduced form model*, that is vector autoregressive model of order one VAR(1)

$$\mathbf{y}_t = \mathbf{b}_0 + \mathbf{W}\mathbf{y}_{t-1} + \mathbf{D}\mathbf{X}_t + \mathbf{z}_t \quad (4)$$

Model (3) can be estimated consistently with the full information maximum likelihood estimation (FIML) when $\mathbf{v}_t$ are normally distributed errors. Note that each equation in our simultaneous model is identifiable as the order and rank condition of parameter matrices are fulfilled (for more details see Greene, 1991: 600–615). This means that we can always also estimate model (4) and recover the structural parameters from it.

The effect of forest conservation on the timber market can be analyzed in at least two alternative ways. We can model the conservation decisions and policy targets by introducing some dummy variables in $\mathbf{X}_t$ corresponding to the time when the timber conservation policies were applied. However, this route is rather cumbersome and impractical as there are many different policy targets with overlapping and non-overlapping operating times, some which are not yet in practice. Alternatively, the *impulse response analysis* based on the VAR model is an appropriate method in this context (see Lütkepohl, 1991). Impulse response analysis provides the answer to the question of how the initial state of a system (3) changes when unpredictable shocks take place in the timber stocks.

In impulse response analysis, the reduced form of model (3) is converted

https://doi.org/10.1017/S1355770X02000189 Published online by Cambridge University Press

into the moving average (MA) presentation form (see appendix A for a derivation of this result) with lag polynomials $\mathbf{R}(L)$ and $\mathbf{W}(L)$

$$\mathbf{y}_t = \mathbf{c}_0 + \mathbf{R}(L)\mathbf{X}_t + \mathbf{W}(L)\mathbf{v}_t \tag{5}$$

where $\mathbf{c}_0 = \mathbf{MA}^{-1}\mathbf{a}_0$, $\mathbf{R}(L) = \mathbf{MA}^{-1}\mathbf{C}$ and $\mathbf{W}(L) = \mathbf{MA}^{-1}$ with $\mathbf{M} = (\mathbf{I}-\mathbf{A}^{-1}\mathbf{B}L)^{-1}$. Matrix $\mathbf{M}$ gives the MA representation. Basically, equation (5) provides the long-run solution to the model specified in (2). This means that, since shocks in the error matrix $\mathbf{v}_t$ influence the long-run behaviour of Q_t, P_t, and Δg_t, we can study the time-series properties of Q_t, P_t, and Δg_t. By identifying these shocks in the timber stock increment Dg_t as conservation policy changes, their long-run effects on the market demand quantities Q_t and the supply P_t are obtained. The identifiability of the structural model (3) allows us to use the VAR-approach in detecting the market equilibrium demand and supply effects of conservation.

In practice if we estimate the VAR(1) model as

$$\mathbf{y}_t = \mathbf{b}_0 + \mathbf{W}\mathbf{y}_{t-1} + \mathbf{D}\mathbf{X}_t + \mathbf{v}_t \tag{6}$$

for Q_t, P_t and Δg_t, we can calculate the impulse responses of shocks in the errors $\mathbf{v}_t$. If these are correlated, for example $\mathrm{cov}(\epsilon_t\ \mu_t) \neq 0$, *orthogonal* shocks are used (Mills, 1992). These are obtained with Choleski decomposition of the covariance matrix $\Omega_v = \mathbf{PP}'$ by defining a diagonal matrix Γ that has the same diagonal as $\mathbf{P}$ and by specifying $\mathbf{G} = \mathbf{P}\Gamma^{-1}$ and $\Lambda = \Gamma\Gamma^{-1}$. Premultiplying (6) by Γ^{-1} gives $\mathbf{w}_t = \Gamma^{-1}\mathbf{v}_t$, which has a diagonal covariance matrix $\Omega_w = \mathrm{cov}(\mathbf{w}_t\mathbf{w}_t') = \Lambda$. However, this decomposition is not unique and the results depend on the order of the variables. This does not affect the present analysis since we always use the policy sensitive variable Δg_t as the last variable.

Data

Our data consist of yearly observations from Finnish roundwood markets for the period, 1958–1995 (38 observations). The market volume index, Q_t, is the quantity of pulpwood purchases from private forests by felling season (million m^3). The price variable, P_t, is measured by the real stumpage price of pulpwood purchased from private forests (FIM/m^3). The real price was obtained by dividing P_t by the wholesale price index.

Logarithmic transformations are used in the estimations (excluding the real interest rate, r_t). Δg_t was replaced with $\Delta \ln g_t$. All transformed series were tested with unit-root tests (DF and ADF tests) for possible non-stationarity. The test results indicated that the series are closer to the stationary alternative than the non-stationary. Figure 1 plots the series $\ln Q_t$, $\ln P_t$, and $\Delta \ln g_t$.

The variable g_t is an approximated annual increase of the timber stock in the non-industrial private forests in Finland. National forest inventory data—as published in the annual Statistical Yearbook of Forestry by the Finnish Forest Research Institute—were interpolated to obtain the figures. Interpolation was based on the assumption of constant growth of forest.

The variable r_t is the real interest rate (average interest rate of bank loans at year end, less the yearly inflation rate). Series for import pulpwood price, pulp price, net fixed capital stock of the forest industry, and timber

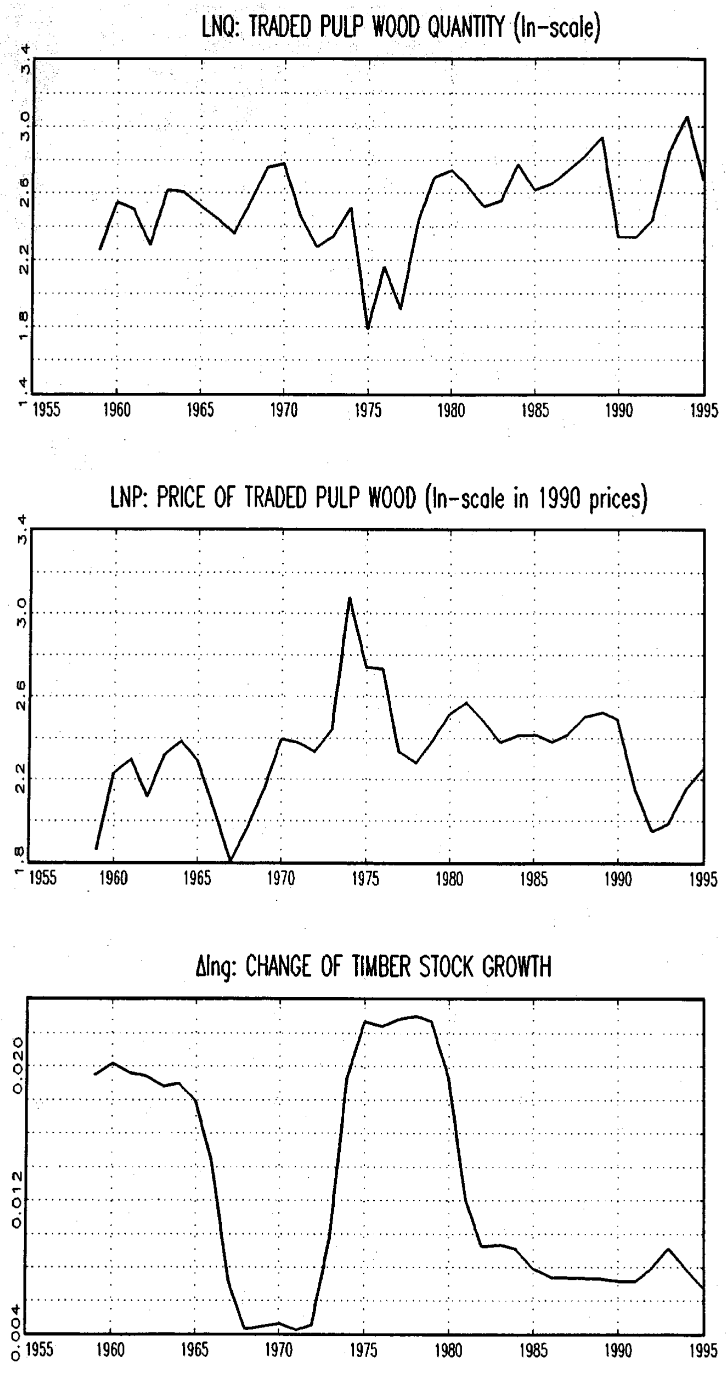

Figure 1. *Traded pulp wood volume, prices and change of private timber stock growth in Finland 1959–1995*

https://doi.org/10.1017/S1355770X02000189 Published online by Cambridge University Press

export volume were also available. However, none of these series were statistically significant when added in alternative specifications to the demand or supply equations in the structural model (1).

4. Estimation of the structural model

Table 1 gives the main estimation results of the structural timber market model. The equation estimates are significant in an econometric sense. The diagnostic tests do not indicate any misspecification. LR test statistics for over-identified restrictions do not reject our restricted specification (that is, zero restrictions in coefficient matrices in model 2).

The short- and long-run standardized price elasticities of pulpwood demand are –0.557 and –0.979. The results for the supply equation are interesting. The interest rate effects (–0.392 and –1.195) reveal that timber sellers make price adjustments in response to real interest rates. Higher interest rates push the supply price down. The result reflects the substitution effects among forest owners between their income from timber-selling and bank loans. Changes in timber stock increment have significant supply price effects: price levels tend to be higher after a conservation act. The short- and long-run impacts of $\Delta \ln g_t$ on $\ln P_t$ are –0.235 and –0.716. The indirect long-run impact of $\ln Q_t$ on supply price is 1.212. This means that long-run supply price elasticity is 0.826. Note, that a reduction in $\Delta \ln g_t$ shifts the supply curve upwards, raising market price. This has its direct effects on the demanded market quantity $\ln Q_t$. However, the lagged timber demand $\ln Q_{t-1}$ has feedback effects on stock adjustment. The total

Table 1. *FIML estimation results for structural timber market model*

Variable	*Coefficient*	*Std. Error*	*t-value*	*Standardized coefficient*	*Long-run solution*
Demand equation: endogenous variable $\ln Q_t$					
Constant	2.752	0.455	6.039	–	5.105
$\ln Q(t-1)$	0.431	0.113	3.792	0.461	–
$\ln P(t)$	−0.557	0.167	−3.325	−0.505	−0.979
Supply equation: endogenous variable $\ln P_t$					
Constant	0.900	0.201	4.491	–	2.744
$\ln P(t-1)$	0.684	0.087	7.779	0.672	–
$r(t)$	−0.022	0.005	−4.147	−0.392	−1.195
$\Delta \ln g(t)$	−8.035	4.171	−1.927	−0.235	−0.716
Stock growth adjustment equation: endogenous variable $\Delta \ln g_t$					
Constant	0.037	0.010	4.491	–	0.123
$\Delta \ln g(t-1)$	0.695	0.083	8.067	0.721	–
$\ln Q(t)$	−0.013	0.004	−3.289	−0.489	−1.697

Notes:
Sample period 1960–1995 (36 observations)
Log likelihood = 345.39
LR test of overidentifying restrictions: $\chi^2(5) = 4.89$ (p-value = 0.42)
Vector residuals normality test: $\chi^2(6) = 10.98$ (p-value = 0.09)
Vector residuals AR(2) test: F(18,71) = 1.17 (p-value = 0.30)
Vector residuals heteroskedasticity test: F(48,97) = 1.15 (p-value = 0.27)

https://doi.org/10.1017/S1355770X02000189 Published online by Cambridge University Press

outcome of these effects determines the simultaneous dynamic long-run outcome of a conservation shock.

5. Impulse response analysis of forest conservation

The econometric results are used in the impulse response analysis. We employ a negative orthogonalized shock of 10 per cent in the errors of the $\Delta \ln g_t$ equation in the VAR(1) model, and interpret this as the initial impact of conservation on the timber market. Note, that the shocks take place in innovations of the equation for $\Delta \ln g_t$ in the MA(∞)-form of the VAR(1) model. The shock in the error term of the $\Delta \ln g_t$ equation affects all endogenous variables of the system. The MA form includes all short- and long-run effects between endogenous variables. The impulse responses for the 20-year period are calculated for $\ln Q_t$, $\ln P_t$, and $\Delta \ln g_t$.

The impulse responses are provided in figure 2, while the accumulated responses over these lag values (that is the total long-run effects) are given in figure 3. As indicated by the timber demand path shown in figure 2 (upper part), the initial conservation effect on the negative timber stocks decreases the demanded quantities until period 7. Thereafter the effects fade away. Over the range of 20 years, the initial 10 per cent reduction in the stock growth translates into a 4 per cent decrease in demand and 18.8 per cent reduction in the change of the stock increment (see figure 3, upper and lower parts). Thus, conservation has adverse quantity effects on the long-run timber demand and stocks. The short-run effects are more conspicuous as there is a weak long-run tendency to recover the state before a conservation shock.

The conservation effects on the timber supply price are also interesting. Generally, the shock has price-raising effects on supply prices. The shock effects are larger and sharper than the effects on demand $\ln Q_t$. The accumulated responses put the new long-run price level at 4.4 per cent higher than before the conservation shock. Most of the price increases take place in six years.

The economic explanation for the timber market effects of a negative stock shock is not difficult to see. Conservation is a direct supply constraint that the timber sellers have to face. Conservation reduces stocks available for harvesting. The supply curve shifts upward. As the timber sellers want to restore their income levels, the increased price level compensates them for their reduced supply. However, in the long-run higher market prices and lower supply do not restore the initial change of stock increment.

A large reduction in the timber supply potential, as represented by a large-scale protection scheme, adversely affects the forest sector's long-run expansion potential. This gradually forces the forest industry to modify its wood-using capacity. Some estimates of the physical effects of forest conservation on Finland's annual allowable cut indicate that conservation brings the reduced timber producing potential of Finnish forests quite close to the forest industry's current wood using capacity (Mestra, 1996). Therefore, a stagnation of the timber markets can be induced by the conservation program in Finland.

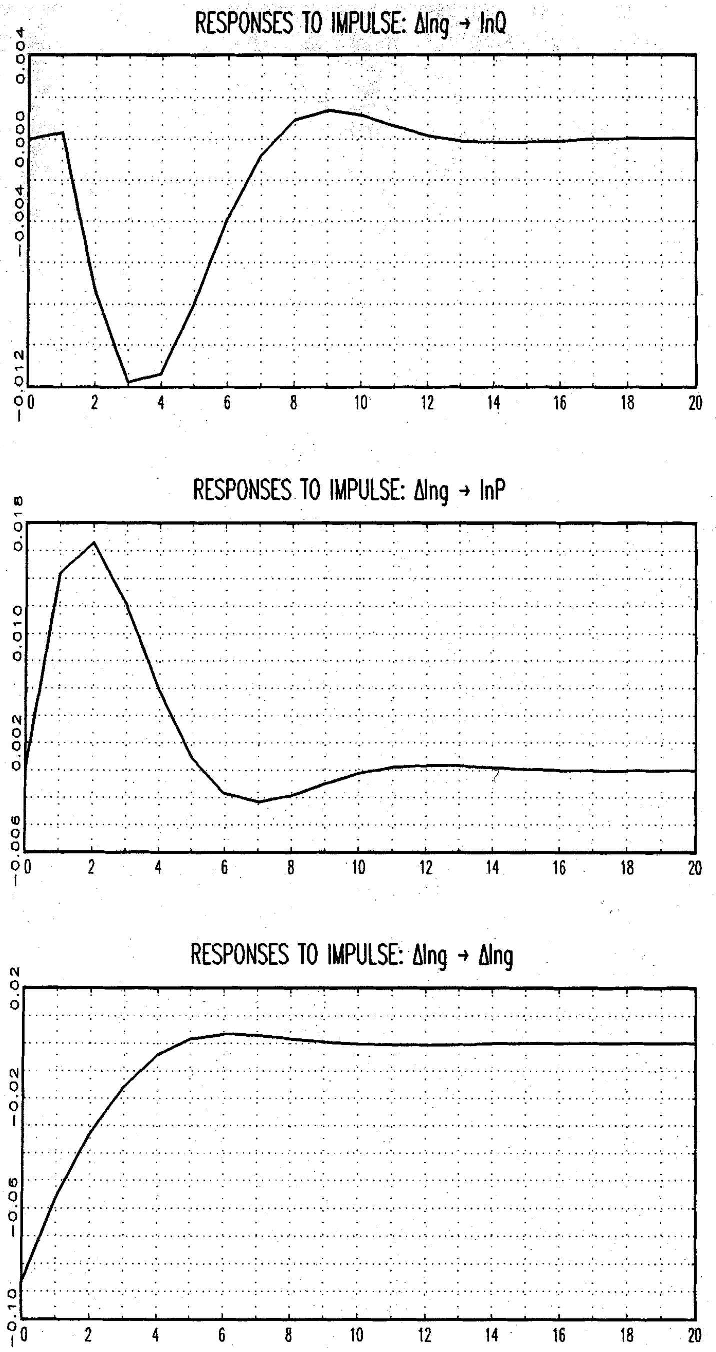

Figure 2. *Twenty year impulse responses of 10 per cent negative shocks in timber stock growth on traded pulp wood, pulp wood prices, and change of stock growth*

https://doi.org/10.1017/S1355770X02000189 Published online by Cambridge University Press

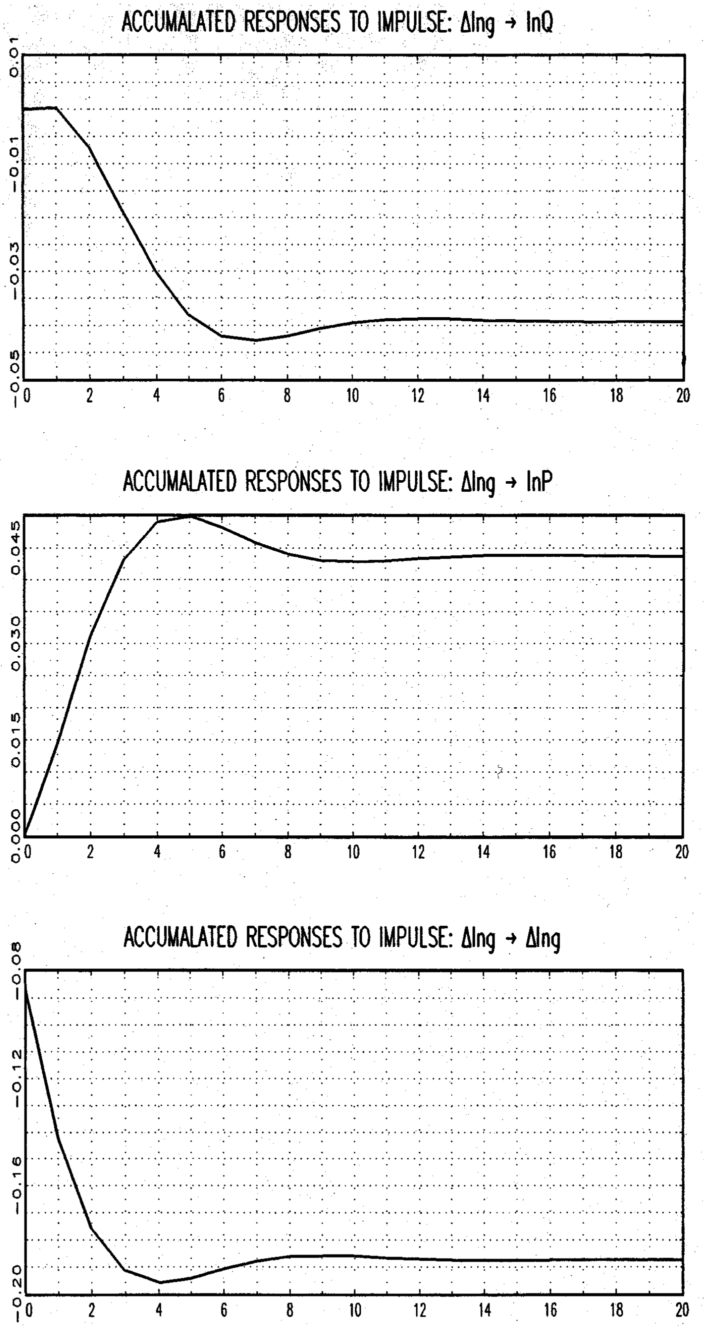

Figure 3. *Accumulated twenty year impulse responses of 10 per cent negative shock in timber stock growth on traded pulp wood, pulp wood prices, and change of stock growth*

https://doi.org/10.1017/S1355770X02000189 Published online by Cambridge University Press

6. Conclusions

In this study we have explored the effects of forest conservation policies on private timber markets by incorporating forest stock dynamics in modelling. We estimated both short-run and long-run effects. Forest conservation has adverse effects on timber supply and quantities traded, as well as on the privately owned commercial timber stock. Timber volumes traded contract by about 4 per cent as a result of a 10 per cent initial decrease in the commercially usable private timber stocks.

The 4 per cent annual reduction in the supply of timber quantities and the 18.8 per cent reduction in the change of the annual increment due to the conservation shock are linked to each other through the forest dynamics as follows. The fact that the traded timber volumes are only moderately affected by forest conservation indicates that the remaining down-sized private forest assets will be managed more intensively than the larger timber assets prior to the conservation policies. The annual timber removals per unit of standing stock increase, thus reducing in the long run the size of the remaining stocks and their growth. In this way private forest owners partially compensate for the negative income effects of the conservation policies.

Timber prices were estimated to increase by 4.4 per cent as a result of the 10 per cent reduction in the commercially usable timber stocks. Together with the 4 per cent decline in the annual timber supplies, this means that the annual timber-selling income received by the private forest owners remains almost unchanged. In this sense, it is not the timber sellers that will lose as a result of the forest conservation act. Rather, the results suggest that it is the wood-utilizing forest industries in Finland that will be the biggest losers. At business cycle peaks forest conservation means lower raw wood supply with higher prices than earlier. In the short run the overall cost level will also rise because of the industry's over-capacity. For the private timber owners the negative effects of conservation come through the decreased commercial value of their timber assets; the timber price increase will not be enough to compensate for the reductions in timber assets.

From an ecological point of view the results imply that the conservation policies may cause intensified harvesting in the remaining commercial forests. Thus, it is possible that the ecological value of these forests will decline as a result of the conservation policies.

Our analysis in this study is subject to some obvious limitations. The demand and supply part of our model described pulp wood markets, while the forest dynamics part was on the level of the increment for the entire timber stocks of the private forests. Thus we assume that trees that are to be protected will have an equal effect on pulpwood and logwood availability. Furthermore, it is possible that the series for the approximated growth of the timber stocks suffers from the limitations of the interpolation of inventory data used. However, the reasonable results obtained give us confidence that the model actually does describe the role of the forest dynamics in an accurate way. Naturally, it remains an issue of further research to find out how widely the results obtained here can be generalized to other cases.

The results obtained in this study indicate that, under developed economic conditions and private ownership of land, the economic effects of forest conservation programmes can be quite significant and far-reaching. As importantly, the results also suggest that economic agents seek for compensatory income from the remaining unprotected forests. In the developing countries, forestland and forests are generally publicly owned. With the widespread open-access practices and lack of land tenure enforcement, the publicly owned forest resources are, however, privately extracted and often depleted to the point where the forests are destroyed and the future of forest resources has become threatened. Under these conditions, it is likely that any total forest conservation efforts, where threatened land is declared protected, would not work effectively (cf. Pearce, 1999). Even if the government would be willing to pay for conservation enforcement and effectively ban the commercial use of the protected land, private agents whose livelihoods depend on forest conversion would be compelled to find compensatory forestland to clear. Thus forest clearing would be shifted from protected land to other areas, leaving the environmental net balance of the conservation act minimal.

In the developing countries, forest resources have been used mostly to further economic development. Undoubtedly forests have, in the form of forestland conversion to agricultural use, contributed to the economic development of these countries. To that extent the loss of forests has been socially justified. However, to turn the 'pro-development' use of forests to a sustainable basis is the real challenge of the future. As far as they can be extended to developing country conditions, the results of this study suggest that total conservation of forests may not be an effective environmental policy measure to move towards more sustainable forest management. Rather, sustainability could be sought after by combining conservation efforts with the economic use of forest resources. If governments and international agencies are genuinely willing to pay for protecting forests, then developing incentives to keep standing timber uncut or subsidising farmers and forest dwellers for the rehabilitation of the so-called secondary forests, seem a better avenue for achieving sustainability than outright conservation of forests.

References

Apsey, M. and F.L.C. Reed (1995), 'World timber resources outlook, current perceptions: a discussion paper', 2nd edition, Council of Forest Industries, Vancouver, BC.

Aronsson, T. (1990), 'The incidence of forest taxation — A study of Swedish roundwood Markets', *Scandinavian Journal of Economics*, **92**: 65–79.

Baharuddin, H.G. and M. Simula (1996), 'Study of the development in the formulation and implementation of certification schemes for all internationally traded timber products', Draft report to the International Tropical Timber Organization, Yokohama, Japan.

Barbier, E.B., N. Bockstael, J.C. Burgess, and I. Strand (1995), 'The linkages between the timber trade and tropical deforestation — Indonesia', *World Economy*, **18**: 411–442.

Bergman, M.A. and R. Brännlund (1993), 'Measuring oligopsony power: an application to the Swedish pulp and paper industry', Umea Economic Studies No. 296, Umea University.

https://doi.org/10.1017/S1355770X02000189 Published online by Cambridge University Press

Bryant, D., D. Nielsen, and L. Tangley (1997), 'The last frontier forests: ecosystems and economies on the edge', World Resources Institute, Washington DC.

Brännlund, R., P.-O. Johansson, and K.G. Löfgren (1985), 'An econometric analysis of aggregate sawtimber and pulp supply in Sweden', *Forest Science*, **31**: 595–606.

Dubois, O., N. Robins, and S. Bass (1995), 'Forest certification', Report to the European Commission, International Institute for Environment and Development, London.

FAO (1997a), 'FAO Provisional outlook for global forest products consumption, production and trade', Prepared by Zhang, D., J. Buongiorno, A. Rytkönen, A. Zhang and S. Zhu, FAO Forestry Department, Policy and Planning Division, Rome.

FAO (1997), 'State of the world's forests 1997', Food and Agriculture Organization of the United Nations.

Finnish Statistical Yearbook of Forestry (1971, 1974, 1979, 1990–91, 1999), Forest Statistics Information Service, Finnish Forest Research Institute.

Greene, W. (1991), *Econometric Analysis*, London: Macmillan.

Hetemäki, L. and J. Kuuluvainen (1991),'Estimating supply and demand for roundwood: how to incorporate the data and theory', Working Paper No. 397, Finnish Forest Research Institute, Department of Forest Economics.

Iremonger, S., C. Ravilious, and T. Quinton (1997), 'A statistical analysis of global forest conservation', in S. Iremonger, C. Ravilious, and T. Quinton, eds., *A Global Overview of Forest Conservation: CIFOR and WCMC*, Cambridge, UK.

Johansson P.-O. and K.G. Löfgren (1985), 'A bargaining approach to the modelling of the Swedish roundwood market', *Land Economics*, **61**: 285–303.

Johns, A.G. (1997), *Timber Production And Biodiversity Conservation In Tropical Rain Forests*, Cambridge University Press.

Kuuluvainen, J., H. Karppinen, and V. Ovaskainen (1996), 'Landowners objectives and non-industrial private timber supply', *Forest Science*, **42**: 300–309.

Lütkepohl, H. (1991), *Introduction to Multiple Time Series Analysis*, New York: Springer-Verlag.

Mestra (1996) (in Finnish), Metsänsuojelun ja työllisyyden rahoitustoimikunnan mietintö: Maa- ja metsätalousministeri, Helsinki, Finland.

Mills, T.C. (1992), *Time Series Techniques for Economists*, Cambridge University Press.

Ministry of Environment (1997), 'Environmental policies in Finland', Background papers for the OECD environmental performance review of Finland, The Finnish Environment 150: Ministry of Environment, Environmental Policy Department, Helsinki, Finland.

Nilsson, S. (1996), 'Do we have enough forests?', IUFRO Occasional Paper 5, Vienna.

OECD (1997), *Environmental Performance Reviews: Finland*, Paris, France.

Pearce, D.W. (1999), ´Economics and biodiversity conservation in the developing world', *Environment and Development Economics*, **4**: 230–233.

Perez-Garcia, J.M. and B.R. Lippke (1993), 'Measuring the impacts of tropical timber supply constraints, tropical timber trade constraints and global trade liberalization', LEEC Discussion Paper 93-03, London Environmental Economics Centre, UK.

Solberg, B. (ed.) (1996), 'Long-term trends and prospects in world supply and demand for wood and implications for sustainable forest management', Research Report 6, European Forest Institute.

Sedjo, R.A. (1996), 'Environmental impacts of forest protection: some complications', in B. Solberg, M. Palo, and P. Hyttinen, eds., *Forest Industries Towards The Third Millennium—Economic and Environmental Challenges*, EFI Proceedings, 11, European Forest Institute.

Sedjo, R.A. and K.S. Lyon (1995), 'A global pulpwood supply model and some implications. Final report IIED', Resources for the Future, Washington DC.

Sedjo, R.A., A.C. Wiseman, D.J. Brooks, and K.S. Lyon (1994), 'Global forest products trade: the consequences of domestic forest land-use policy', RFF discussion paper 94-13, Resources for the Future, Washington, DC.

Sohngen, B., R. Mendelsohn, and R.A. Sedjo (1999), 'Forest management, conservation, and global timber markets', *American Journal of Agricultural Economics*, **81**: 1–13.

Van Kooten, G.C., R.A. Sedjo, and E.H. Bulte (1999), 'Tropical deforestation: issues and policies', in H. Folmer and T. Tietenberg, eds., *The International Yearbook of Environmental and Resource Economics 1999/2000*, Edward Elgar Publishing.

Varangis, P.N., R. Crossley, and C.A. Primo Braga (1995), 'Is there a commercial case for tropical timber certification?', Policy Research Working Paper 1479, The World Bank, Washington DC.

Zuidema, G., G.J. van den Born, J. Alcamo, and A. Kreileman (1994), 'Simulating changes in global land cover as affected by economic and climatic factors', *Water, Air, and Soil Pollution*, **76**: 1–21.

Appendix A

The derivation of the VAR(1) model and MA representation

Start from the basic model

$$\mathbf{A}\mathbf{y}_t = a_0 + \mathbf{B}\mathbf{y}_t + \mathbf{C}\mathbf{X}_t + \mathbf{v}_t$$

If **A** is an invertible matrix we get the reduced VAR(1) form by multiplying this equation from the left by $\mathbf{A}^{-1}$

$$\mathbf{y}_t = \mathbf{A}^{-1}(\mathbf{a}_0 + \mathbf{B}\mathbf{y}_t + \mathbf{C}\mathbf{X}_t + \mathbf{v}_t)$$
$$= \mathbf{b} + \mathbf{W}\mathbf{y}_{t-1} + \mathbf{D}\mathbf{X}_t + \mathbf{z}_t.$$

Next, move all the endogenous variables on the left side (L is the lag operator, $\mathrm{L}x_t = x_{t-1}$)

$$(\mathbf{I}-\mathbf{W}L)\mathbf{y}_t = \mathbf{b}_0 + \mathbf{D}\mathbf{X}_t + \mathbf{z}_t.$$

Now, if $\mathbf{I}-\mathbf{W}L = (\mathbf{I}-\mathbf{A}^{-1}\mathbf{B}L)$ is invertible, the MA representation

$$\mathbf{Y}_t = \mathbf{M}(\mathbf{b}_0 + \mathbf{D}\mathbf{X}_t + \mathbf{z}_t)$$

is obtained where $\mathbf{M} = (\mathbf{I}-\mathbf{A}^{-1}\mathbf{B}L)^{-1}$.