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A SOVIET MODULE FOR THE GLOBAL FOREST SECTOR MODEL

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FOREWORD

The objective of the Forest Sector Project at IIASA is to study long-term development alternatives for the forest sector on a global basis. The emphasis in the Project is on issues of major relevance to industrial and governmental policy makers in different regions of the world who are responsible for forest policy, forest industrial strategy, and related trade policies.

The key elements of structural change in the forest industry are related to a variety of issues concerning demand, supply, and international trade in wood products. Such issues include the growth of the global economy and population, development of new wood products and of substitute for wood products, future supply of roundwood and alternative fiber sources, development of new technologies for forestry and industry, pollution regulations, cost competitiveness, tariffs and non-tariff trade barriers, etc. The aim of the Project is to analyze the consequence of future expectations and assumptions concerning such substantive issues.

The research program of the Project includes an aggregated analysis of long-term development of international trade in wood products, and thereby analysis of the development of wood resources, forest industrial production and demand in different world regions. The analysis is carried out by means of a model of the global sector. The purpose of this article is to describe the preliminary model of the Soviet forest sector in connection with a global model. Some historical data, statistical forecasts as well as simulation runs with the model for demonstration purposes are presented.

Markku Kallio
Leader
Forest Sector Project

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INTRODUCTION

The purpose of this paper is to suggest how a module representing a centrally planned economy (e.g., the USSR) can be included in the IIASA's Global Trade Model (GTM) (Dykstra and Kallio 1984). Any such module must reflect the main features of the planned economy and at the same time it must be compatible with the GTM. The primary assumptions concerning the planned-economy module are:

(a) Consumption of forest products outside the forest sector (e.g., sawnwood and panels for construction, paper for printing, etc.) is specified by ***target levels*** and by a ***penalty*** for deviating from such levels. Such penalty may be considered, for instance, as the ***social cost*** of not meeting the target levels.

(b) The annual target levels of final forest products and their dynamics are generated or specified exogenously resulting from long-term state plans or scenarios. For instance, a permanent reduction in imports or an increase in revenues from exports can be typical scenarios. In a more fully developed version of the model, the target levels can be defined endogenously through an input-output submodel whose target levels of production for forest products consuming industries are exogenous.

(c) The structure of the forest industry is developed independently from world prices of forest products.

(d) Domestic prices are independent of world prices.

(e) Foreign trade in forest products is required to meet two main constraints: first, for total imports there is an exogenously given budget, and second, for exports there is an exogenously specified minimum total revenue. Imports and exports shall also satisfy exogenously specified trade inertia constraints, trade agreements, quotas and other trade policy requirements. *Efficiency* in trade is assumed to result from maximizing what we shall call the ***trade surplus*** subject to all these constraints. Trade surplus is the net revenue from exports (negative terms from import) after transportation costs and after the *social cost* of exporting commodities from the economy (a benefit from importing). Note that such an efficiency criterion directs the exports (under the specified limits) to regions so that the FOB price (i.e., the export price at the Soviet border) is the highest possible. Similarly, imports are chosen from regions which provide the lowest CIF price (i.e., the import price at the border).*

(f) The mathematical structure of the model (or more accurately its computerized version) has to permit the possibility of improving individual modules. This will allow the use of submodels which are under preparation in the collaborating research institutes.

An outline of the Soviet module is shown in Figure 1. As illustrated, the module contains three main sub-modules: demand, production, and exchange (with the GTM). We are aware that some of the assumptions made in formulating this model (see, for instance, (c) and (d)) are a rather rough approximation of reality. However, they simplify the mathematical structure of the model significantly without unreasonably contradicting the existing data.

* FOB = "Free On Board" (i.e., the FOB price does not include transport costs, duties, etc.)
CIF = "Cost, Insurance, and Freight" (i.e., the CIF price includes delivery charges to the destination).

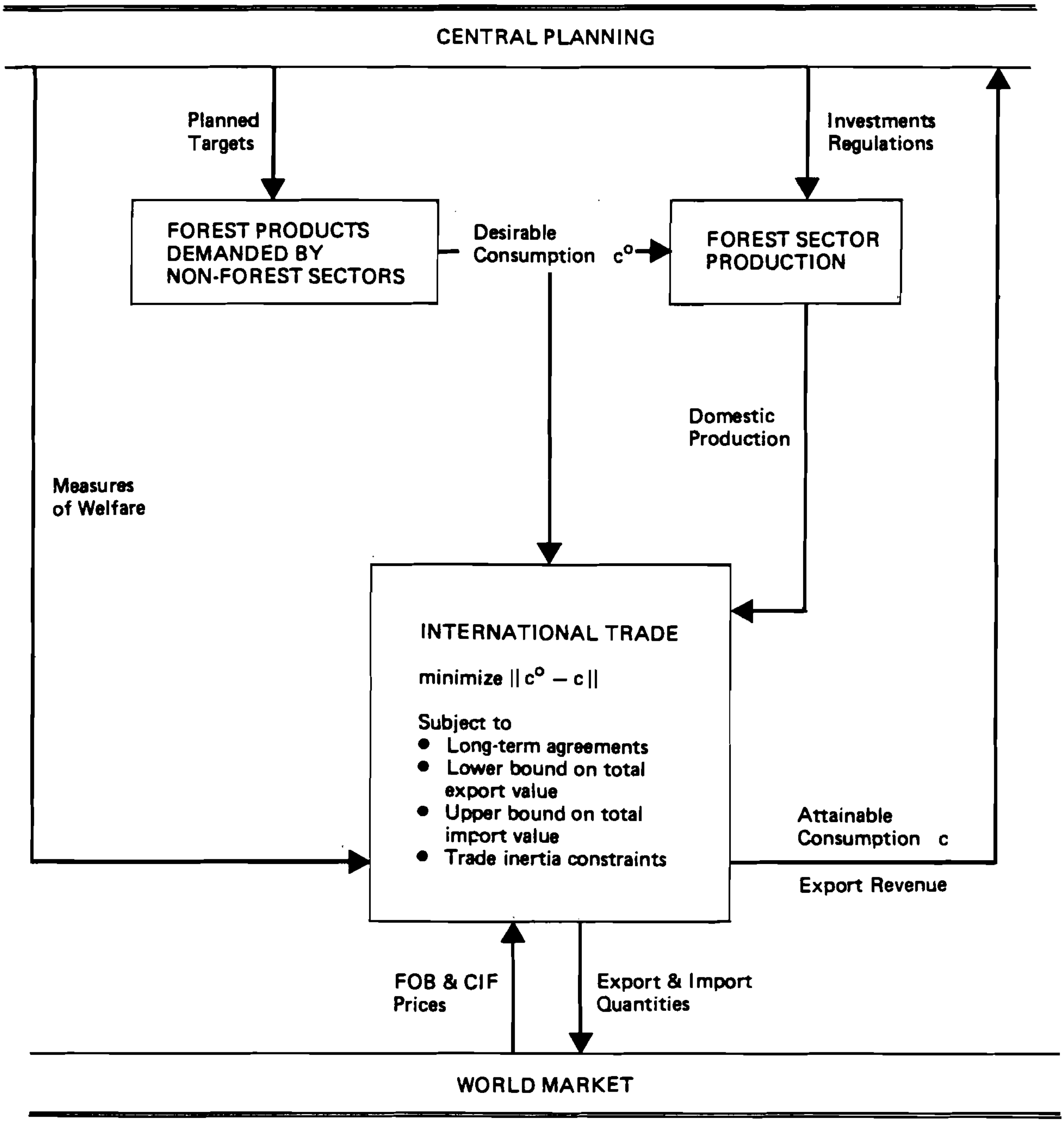

FIGURE 1. Structure of the Soviet forest sector model.

REGIONAL SUBDIVISION AND PRODUCT CLASSIFICATION

The preliminary **GTM** with the Soviet module included comprises seven regions and nine product categories, as shown in Table 1. This is a static (one-year) model for which the parameters may be set to correspond to a specific point in time, but dynamic developments can be simulated by executing a stepwise series of runs.

TABLE 1. Regional and product definitions

Regions	**Product Definitions**
Northern Europe	Logs
Western Europe	Pulpwood
USA	Sawnwood
Canada	Panels
Japan	Pulp
USSR	Newsprint
Rest of the World	Other printing & writing papers
	Packaging paper & boards
	Recycled paper

PRODUCTION

We shall at first discuss the standard production module which is used for all regions except the Soviet Union. Production here refers not only to the conversion of raw materials into final products, but also to wood raw material production and recycling of waste paper. Relevant data for the USSR are summarized in Table 2. After describing the general structure of the production model, we discuss each type of production activity separately.

In the discussion that follows, index s refers to the USSR whereas indices i and j are used for any region (including possibly the USSR). Let an index m refer to a production activity and let y_{im} be the level of annual production in region i associated with that activity. Denote by $y_i = (y_{im})$ the vector of gross production in region i. A single activity m may produce one or more commodities (as a main product, a side product or as a residual) and it may consume one or more commodities as inputs. Let A_{ikm} be the net output of commodity k per unit of production for activity m in region i. A positive value for A_{ikm} implies production of commodity k and a negative value implies an input of raw material k into production process m. Let $A_i = (A_{ikm})$ be the matrix of such coefficients and A_{im} its m-th column vector (i.e., the coefficients for activity m). There is one row in A_i for each product k (including both raw materials, such as logs, and final products, such as sawnwood), and one column for each production activity m. In this notation, the vector of net production (having one component for each product k) is given by $A_i y_i = \sum_m A_{im} y_{im}$.

Associated with each production activity m in region i, $i \neq s$, is a resource (or available capacity) upper limit K_{im} so that

$$y_i \leq K_i \qquad (1)$$

TABLE 2. Production and trade statistics for forest products in the USSR. (Sources: USSR (various years), *Statistika* (1982), UNIDO (1983))

Product	1960	1970	1975	1980	1981
LOGS (coniferous & nonconiferous)					
Production (mill. m^3)	–	167.0	171.0	152.0	152.0
Exports (mill. m^3)	–	7.4	8.5	6.6	6.3
Exports as percentage of production	–	4.4	5.0	4.3	4.1
Imports (mill. m^3)	–	0.1	0.3	0.3	0.3
PULPWOOD & CHIPS (conif. & nonconif.)					
Production (mill. m^3)	–	33.0	42.7	37.8	37.7
Exports (mill. m^3)	–	6.6	8.5	7.8	7.9
Exports as percentage of production	–	20.0	19.9	20.6	21.0
Imports (mill. m^3)	–	0.0	0.0	0.0	0.0
SAWNWOOD (coniferous & nonconiferous)					
Production (mill. m^3)	105.5	116.4	116.2	98.2	98.1
Exports (mill. m^3)	5.0	8.0	7.8	7.1	6.9
Exports as percentage of production	4.7	6.9	6.7	7.2	7.0
Imports (mill. m^3)	–	0.29	0.32	0.36	0.39
WOOD-BASED PANELS					
Production (mill. ton)	–	6.0	9.3	10.6	11.0
Exports (mill. ton)	–	0.20	0.58	0.96	1.01
Exports as percentage of production	–	3.3	6.2	9.1	9.2
Imports (mill. ton)	–	0.09	0.08	0.19	0.13
PULP					
Production (mill. ton)	2.3	6.7	8.6	8.9	9.1
Exports (mill. ton)	0.24	0.45	0.52	0.82	0.84
Exports as percentage of production	10.4	6.7	6.0	9.2	9.2
Imports (mill. ton)	0.08	0.29	0.24	0.22	0.27
NEWSPRINT					
Production (mill. ton)	0.43	1.10	1.36	1.53	1.53
Exports (mill. ton)	0.10	0.26	0.28	0.32	0.32
Exports as percentage of production	23.2	23.6	20.6	20.9	20.9
Imports (mill. ton)	–	0.09	0.05	0.03	0.05
PRINTING & WRITING PAPER					
Production (mill. ton)	2.3	4.2	5.2	5.3	5.4
Exports (mill. ton)	0.12	0.48	0.62	0.65	0.66
Exports as percentage of production	5.2	11.3	11.8	12.2	12.2
Imports (mill. ton)	0.07	0.42	0.48	0.69	–
PACKAGING & BOARD					
Production (mill. ton)	0.9	2.5	3.4	3.5	3.6
Exports (million. ton)	–	0.25	0.30	0.37	0.39
Exports as percentage of production	–	9.8	9.1	100.8	10.9
Imports (mill. ton)	0.04	0.06	0.09	0.21	–

where $K_i = (K_{im})$. The marginal production cost, denoted by $Q_{im}(y_{im})$, is assumed to be a non-decreasing function of activity level y_{im}, for each i and m.

For the forest industries, activities m refer to production processes such as sawmilling and panel production as well as the production of pulp and different types of paper. For a single commodity k there are two or three production activities m referring to alternative technologies. These are: (a) the current technology existing in mills, possibly divided into two efficiency categories, and (b) state-of-the-art technology to be employed in new investments. We shall fix the upper limit K_{im} for new investments to a given share of existing capacity in region i, $i \neq s$, for the same commodity. The marginal cost Q_{im} is assumed to be independent of production level for all forest industry activities m. The efficiency differences among alternative technologies appear both in marginal cost coefficients Q_{im} and in the input-output coefficient vectors A_{im}.

Recycled paper and board is used in the production of newsprint and of packaging paper and board. The marginal cost of recycling is assumed constant. The upper limit K_{im} for each region $i \neq s$ is assumed to be proportional to paper consumption during preceding years.

A harvesting activity m is assumed to yield logs and pulpwood in given proportions. For harvesting of small trees the share of logs may be zero. The marginal cost Q_{im} of harvesting is assumed to be a strictly increasing function of the quantity y_{im}. A suitable functional form is, for instance,

$$Q = \alpha y^{\beta} \tag{2}$$

where α and β are positive. An explicit upper limit is usually not needed on the harvesting volume y. Increasing marginal costs are thus used as surrogates for explicit timber supply constraints. For wood production, two technical activities have been included. One of these provides for the conversion of logs into pulpwood at no extra cost (if necessary to satisfy pulpwood demand), and the other permits the stock-piling of pulpwood in case of overproduction during the current period (as a byproduct of log production from large trees, for instance). For such pulpwood there is a compensation proportional to volume accounting for the pulpwood cost, which is included in harvesting costs.

The production of forest products for the USSR in the preliminary version of the model is projected by regression models. The legitimacy of this is based on assumption (c) from the introductory section and by the stability of observed long-term growth rates in the Soviet forest industry. Figures 2 through 6 contain the graphical presentation of the regression models for the production of the final commodities considered in the preliminary model. Figures 7 and 8 show sawlog and pulp production time series and projections to 2000. These projections are not actually used in the GTM, since sawlogs and pulp are not final products. The figures are merely included here for reference.

In the regression equations, the level of production of roundwood and a time variable were used in all cases as the predictor variables. The vertical lines associated with the projected values for 1985—2000, representing a range of two standard deviations about the projected values, are reminders that the validity of the projected production levels should not be overestimated. For most products, production levels at the end of the 1970s and beginning of the 1980's experienced some instability, and this is naturally reflected in the projections. All projections for the future were done under the assumption that the production of roundwood will be at the 1980 level. It was approximately 350—360 million m^3 during the last five years.

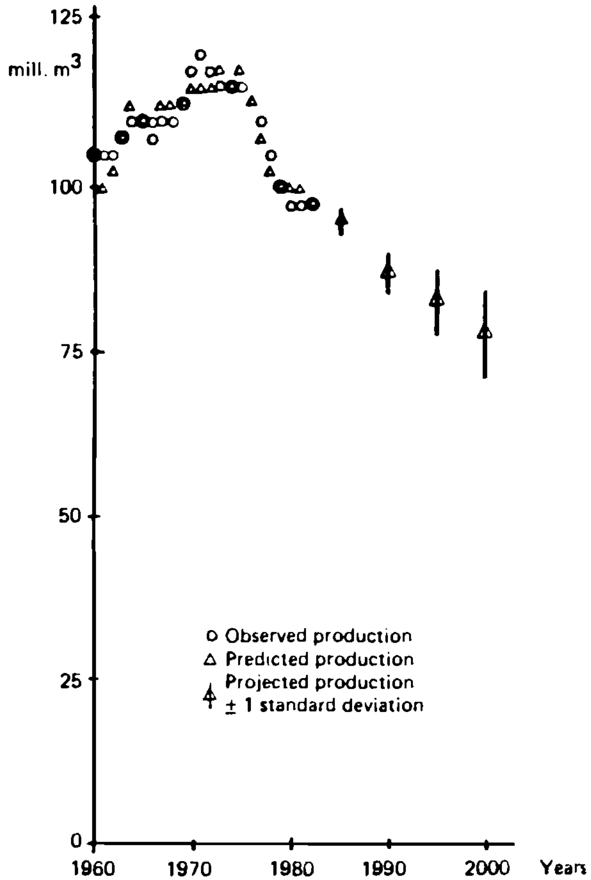

FIGURE 2. USSR sawnwood production.

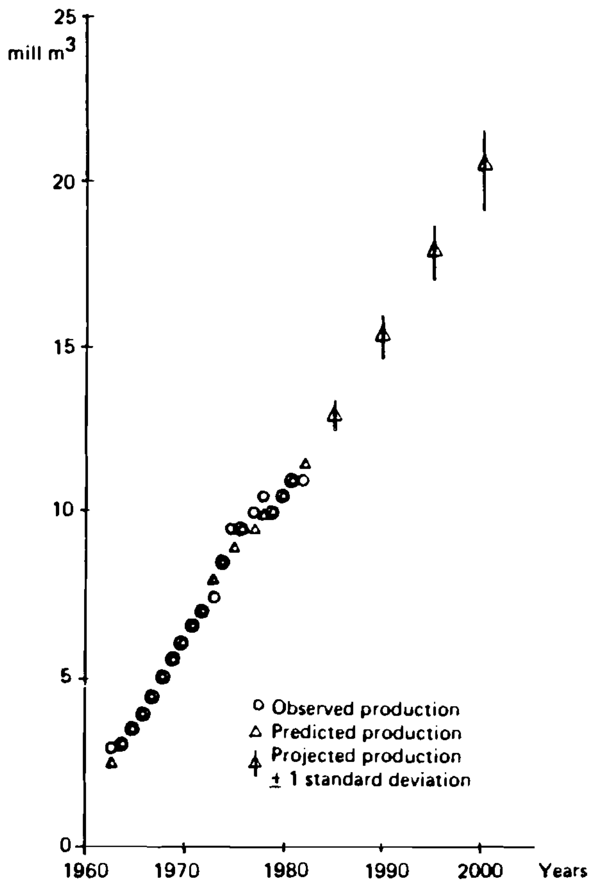

FIGURE 3. USSR wood-based panel production.

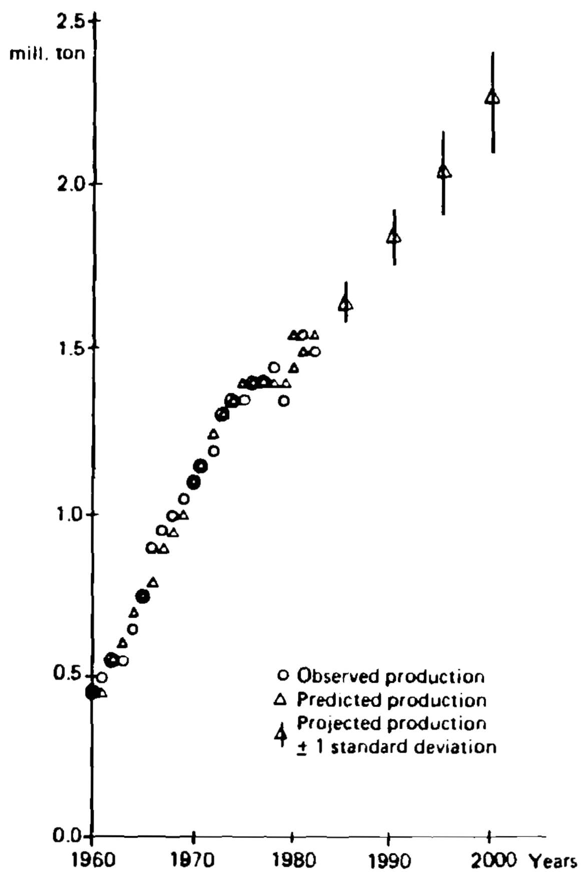

FIGURE 4. USSR newsprint production.

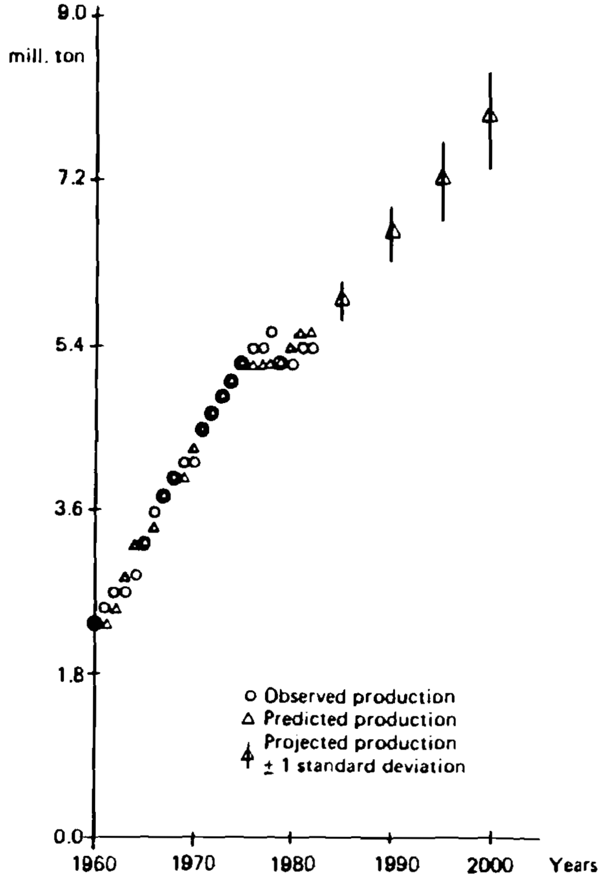

FIGURE 5. USSR printing and writing paper production other than newsprint.

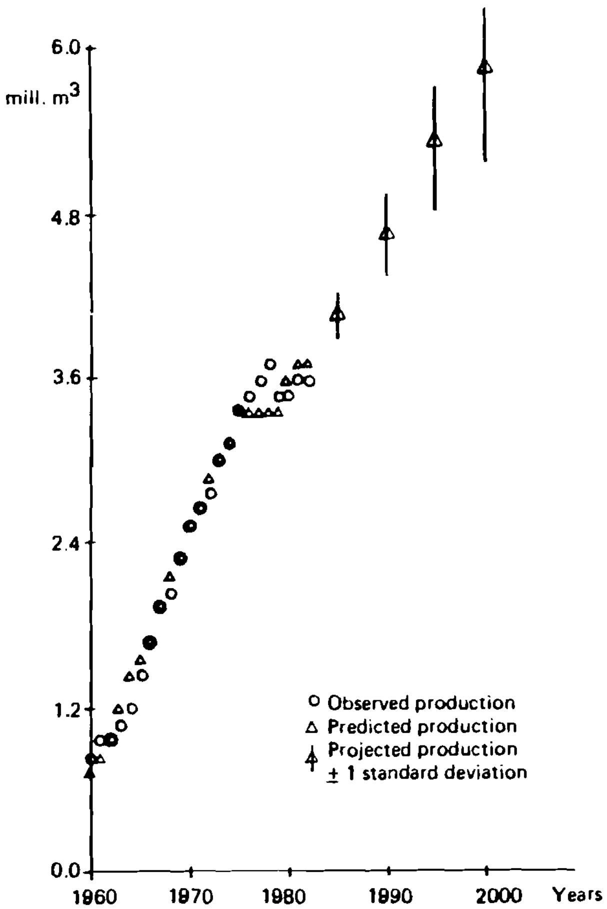

FIGURE 6. USSR packaging paper and board production.

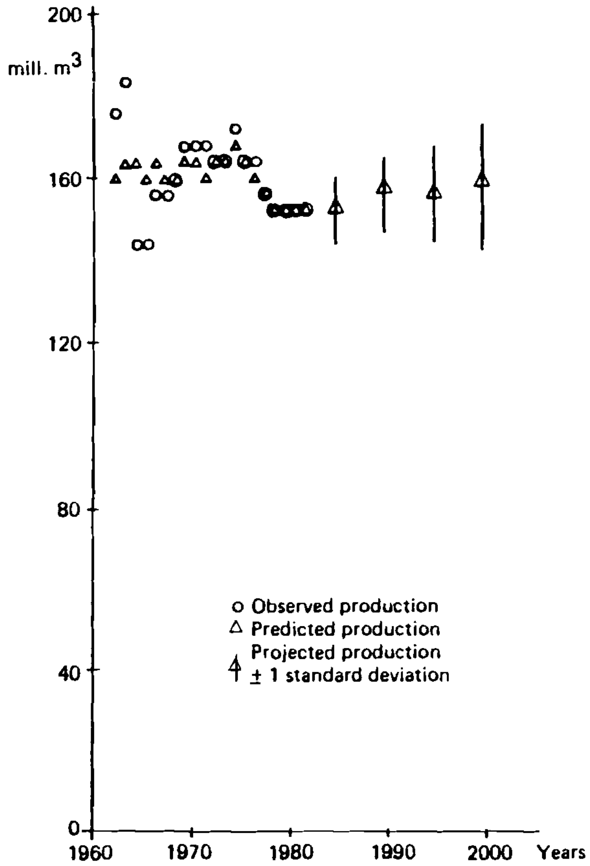

FIGURE 7. USSR sawlog production.

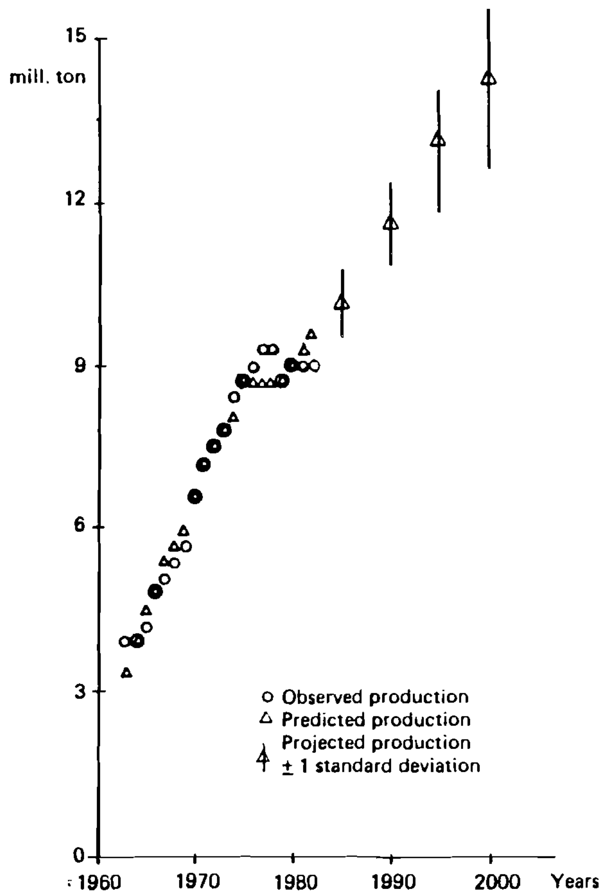

FIGURE 8. USSR pulp production.

Table 3 summarizes the regression models used to prepare the figures and incorporated into the present version of the Soviet module of the **GTM**. These models have the following basic form:

$$\text{RESPONSE}\ (t) = \vartheta(t)\text{ROUNDWOOD}_t + \varepsilon_t\ ,$$

where t is the time variable (t = CURRENT YEAR - 1960), ROUNDWOOD_t = the production of coniferous and nonconiferous logs, round pulpwood, and fuelwood during period t, and ε_t is the error term. The function $\vartheta(t)$ was approximated by either of the following:

$$\vartheta_1 + \vartheta_2 t \quad \text{or} \quad \vartheta_1 + \vartheta_2 t + \vartheta_3 t_1$$

In the latter function, t_1 is zero when $t \le 15$; otherwise $t_1 = t - 15$. This type of splined function is sometimes used to represent the "saturation" effect commonly observed in improving technologies. The values of ϑ_1 can be interpreted as technological coefficients, with ϑ_2 and ϑ_3 representing changes in these coefficients over time. From the formal statistical point of view all of the models appear to fit the observed data very well.

Some 16 regression models were fitted to production data for the Soviet Union. A summary of these models, including some that were not used in the **GTM**, is attached to this paper as an appendix.

TABLE 3. Regression models used for projecting forest products production in the USSR. Only final products are included, since demand for raw materials is derived from final-product demand rather than being projected independently. Current year = 1960 + t, and $t_1 = \max\{t-15,0\}$. Numbers in brackets are t-ratios of the associated parameter estimates.

Regression equation	R^2
$\text{SAWNWOOD}_t = (0.2851 + 0.0015t - 0.0045t_1)\ \text{ROUNDWOOD}_t$ [96.9] [4.2] [6.2]	0.9996
$\text{PANELS}_t = (0.0026 + 0.0014t)\ \text{ROUNDWOOD}_t$ [5.9] [41.9]	0.9986
$\text{NEWSPRINT}_t = (0.00117 + 0.00017t - 0.00006t_1)\ \text{ROUNDWOOD}_t$ [19.5] [23.1] [4.2]	0.9988
$\text{PRINTING}_t = (0.00623 + 0.00050t - 0.00015t_1)\ \text{ROUNDWOOD}_t$ [31.4] [20.4] [3.0]	0.9996
$\text{PACKAGING}_t = (0.0018 + 0.00047t - 0.00016t_1)\ \text{ROUNDWOOD}_t$ [8.9] [14.0] [3.2]	0.9974

INTERNATIONAL TRADE AND MARKET INERTIA

Let e_{ijk} be the quantity of commodity k exported from region i to region j for each i, j, and k. Proportional to the quantity e_{ijk} is a transportation cost of D_{ijk} per unit of commodity k. This may include a tariff (proportional to quantity) or it may account for an export subsidy. Let $e_{ij} = (e_{ijk})$. To represent market inertia, we may set upper and lower limits, U_{ij} and L_{ij}, on trade flows:

$$L_{ij} \leq e_{ij} \leq U_{ij} \tag{3}$$

Such bounds may account for certain types of trade policies as well. In an extreme case, a trade flow may be fixed. If a trade flow $e_{ijk,t-1}$ existed during preceding time period $t-1$, we may set the bounds proportionally:

$$L_{ijk} = \psi_{ijk} e_{ijk,t-1} \tag{4}$$

and

$$U_{ijk} = \omega_{ijk} e_{ijk,t-1} \tag{5}$$

where ψ_{ijk} and ω_{ijk} are positive parameters.

For the USSR, according to assumption (e) from the introduction, two additional trade constraints have to be fulfilled:

$$\sum_{jk} (\pi_{jk} - D_{sjk})\, e_{sjk} = E_s \geq E_s^o, \tag{6}$$

and

$$\sum_{ik} (\pi_{ik} + D_{isk})\, e_{isk} = M_s \leq M_s^o,$$

where π_{ik} are prices, E_s^o is the given lower limit on total export revenues, M_s^0 is the upper limit on total expenditures for imports. These bounds can be taken from long-term plans or chosen according to scenarios (for instance, vanishing of imports for some commodities).

CONSUMPTION

For each k and i, $i \neq s$, the relation between price π_{ik} and level of consumption c_{ik} is given by a price (or inverse consumption) function

$$\pi_{ik} = P_{ik}(c_{ik}) \tag{6}$$

Typically, this is assumed to be a monotonically nonincreasing function. Consumption $c_i = (c_{ik})$ refers to demand in region i ***outside the forest sector***. Therefore we may assume that such consumption of logs, pulpwood, pulp and recycled paper is negligible. For the remaining commodities (which we refer to as ***final products***), the following type of price function is assumed (corresponding to a Cobb-Douglas type of consumption function):

$$\pi_{ik} = \lambda_{ik} c_{ik}^{-\gamma_{ik}} \tag{7}$$

where $-1/\gamma_{ik}$ is the price elasticity coefficient of demand and λ_{ik} is the location parameter for the demand curve.

For the USSR, let c_{sk}^0 be an exogenous target level of consumption for each commodity k and let $P_{sk}(c_{sk})$ the ***marginal penalty*** (per product unit) at consumption level c_{sk} for deviating from the target level c_{sk}^0. A convenient functional form for such penalty would be

$$P_{sk}(c_{sk}) = \pi_{sk}^0 (c_{sk} / c_{sk}^0)^{-\gamma_{sk}}$$

$$= \lambda_{sk} c_{sk}^{-\gamma_{sk}} ,$$

where

$$\lambda_{sk} = \pi_{sk}^0 (c_{sk}^0)^{\gamma_{sk}}$$

and parameter π_{sk}^0 is the marginal penalty at the target level c_{sk}^0 of consumption. In this notation, the mathematical structure of the penalty conforms to the consumption function (7).

At the preliminary stage, desired consumption levels are taken as exogenous scenarios. The topic for a subsequent paper is to estimate such levels taking the planned levels of production in non-forest sectors as a starting point.

SOLUTION PRINCIPLE

For all regions except the USSR, we shall assume that each producer and trade agent (representing each production and trade activity, respectively) is a profit maximizer and that each consumer purchases from the producer (or trader) who offers the lowest price. For the USSR, we assume that for imports there is a budget M_s and for exports there is an export revenues requirement E_s. Define the ***trade surplus*** as the net revenue from exports and imports (after transportation costs) minus the total penalty (of deviating from the consumption targets). Soviet trade is then assumed to result from maximizing the trade surplus subject to the import budget, the export revenue requirement and trade inertia constraints.

Given any prices π_{ik} for each region i and commodity k, profit maximization results in a certain supply of commodities in each region. Similarly, trade surplus maximization results in a given supply from the USSR. If, for all i and k, such supply equals consumption (as determined by a consumption function or through trade surplus maximization), then π_{ik} is an ***equilibrium*** price.* As will be shown below, such an equilibrium can be obtained as a solution of the following optimization problem: Find c_i, y_i and e_{ij}, for all i and j, to

$$\text{maximize } [\sum_{ik} \int_0^{c_{ik}} P_{ik}(c)dc - \sum_{im} \int_0^{y_{im}} Q_{im}(y)dy - \sum_{ijk} D_{ijk} e_{ijk}] \tag{8}$$

subject to

$$c_i - A_i y_i + \sum_j (e_{ij} - e_{ji}) = 0 \qquad \text{for all } i \tag{9}$$

$$0 \leq y_{im} \leq K_{im} \qquad \text{for all } m \text{ and } i \neq s \tag{10}$$

* Note: because of multiple options for regional production and trade models, supply may not equal demand even if equilibrium prices are used. In such a case, however, an appropriate choice (e.g., the one discussed below) of such optimal solutions results in balanced supply and demand.

$$L_{ijk} \le e_{ijk} \le U_{ijk} \qquad \text{for all } i, j \text{ and } k \tag{11}$$

and subject to the trade requirements for $i = s$:

$$\sum_{j,k} (\pi_{jk}^{*} - D_{sjk})\, e_{sjk} = E_s \ge E_s^o \tag{12}$$

$$\sum_{j,k} (\pi_{jk}^{*} + D_{jsk})\, e_{jsk} = M_s \le M_s^o \tag{13}$$

Here the Soviet net production $A_s y_s = y_s^o$ is exogenously given for final products (see Tables 2 and 3 and Figures 2-6), and therefore capacity constraint (10) for $i = s$ as well as production costs Q_{im} in (8) shall be omitted.

The price vector π^* should in principle be endogenous. However, such a formulation would cause major complications for the solution procedure of the model, yet the gains are likely to be minimal from substantive point of view. Therefore, we assume that π^* is exogenously given (possibly separately for import and export) for the trade balance requirements (12)–(13).

The maximization of objective function (8) identifies the point at which the demand and supply are in balance, thus providing the equilibrium price and consumption quantity. Equations (9) represent material balance; i.e., consumption is equal to net production minus net export. Resource constraints are given by (10) and trade inertia constraints by (11).

ANALYSIS OF THE SOLUTION

We shall employ standard optimization theory to show that an optimal solution for (8)-(13) is an equilibrium solution to our model of production, consumption and international trade. Furthermore, the equilibrium price vectors $\pi_i = (\pi_{ik})$ can be obtained as optimal dual solutions to constraints (9). For $i = s$, the USSR, the interpretation of such price vector is the vector of marginal penalties of deviating from target consumption levels. Optimality conditions shall be used for further analysis of the equilibrium. Let $c_i = c_i^*$, $y_i = y_i^*$ and $e_{ij} = e_{ij}^*$ be an optimal solution to (8)-(13) and let π_i, μ_{im} and δ_{ijk} be an optimal dual solution corresponding to the constraints (9), and the upper bounds (10) and (11), respectively. Let ξ_s and ψ_s be the dual solution for (12) and (13) respectively. Defining $\xi_i = \psi_i = 0$ for $i \ne s$, the optimality conditions for (8)-(13) may then be stated as shown in Table 4.

To show that an optimal solution is an equilibrium, let π_{ik} be the price of commodity i in region $i \ne s$, for all i and k. Consider three types of economic agents in each region: the consumers, producers (one corresponding to each production activity m) and export trading agencies (one for each commodity k and trade flow). The consumers purchase in domestic markets, for which the prices are given by vector π_i. Producers buy inputs and sell outputs in domestic markets, whereas trading agencies buy in domestic and sell in foreign markets.

According to (ii) in Table 4 the price π_{ik} and consumption c_{ik}^* are clearly in balance. Given optimal dual prices π_i, for producer m in region i exporting to region j, the problem of profit maximization is to find y_{im} to

$$\text{maximize} \quad \pi_i A_{im} y_{im} - \int_0^{y_{im}} Q_{im}(y)\,dy \tag{14}$$

TABLE 4. Equilibrium conditions of the Global Trade Model.

(i)	c_i^*, y_i^* and e_{ij}^* satisfy (9)-(11),	for all i,j
(ii)	$\pi_{ik} = P_{ik}(c_{ik}^*)$	for all i,k
(iii)	$\pi_i A_{im} - Q_{im}(y_{im}^*) - \mu_{im} \leq 0$	for all $i \neq s, m$
(iv)	$(\pi_i A_{im} - Q_{im}(y_{im}^*) - \mu_{im}) y_{im}^* = 0$	for all $i \neq s, m$
(v)	$\mu_{im} \geq 0$	for all $i \neq s, m$
(vi)	$\mu_{im}(K_{im} - y_{im}^*) = 0$	for all $i \neq s, m$
(vii)	$-D_{ijk} - \pi_{ik} + \pi_{jk} - \delta_{ijk} + \pi_k^* \xi_i - \pi_k^* \psi_j \leq 0$	for all i,j,k
(viii)	$(-D_{ijk} - \pi_{ik} + \pi_{jk} - \delta_{ijk} + \pi_k^* \xi_i - \pi_k^* \psi_j)(e_{ijk}^* - L_{ijk}) = 0$	for all i,j,k
(ix)	$\delta_{ijk} \geq 0$	for all i,j,k
(x)	$\delta_{ijk}(U_{ijk} - e_{ijk}^*) = 0$	for all i,j,k
(xi)	$\xi_s, \psi_s \geq 0$	for $i = s$
(xii)	$\xi_s = \psi_i = 0$	for $i \neq s$

$$\text{s.t.} \quad 0 \leq y_{im} \leq K_{im}. \tag{15}$$

One can readily check that (i) and (iii)-(vi) are the optimality conditions for this problem. Thus y_{im}^* is a profit maximizing solution for producer m. Note that y_{im}^* may not be a unique optimum for (14)–(15), and for an arbitrary set of optimal solutions constraint (9) may be violated. For a trading agency of commodity k in region i exporting to region j, the profit maximization problem is to find e_{ijk}, for all j, to

$$\text{maximize} \quad (\pi_{jk} - \pi_{ik} - D_{ijk}) e_{ijk} \tag{16}$$

$$\text{s.t.} \quad L_{ijk} \leq e_{ijk} \leq U_{ijk} \tag{17}$$

and in case of exports to the USSR additionally

$$\pi_k^* e_{isk} \leq M_s - \sum_{k,j \neq i} \pi_k^* e_{jsk}^* - \sum_{k,j \neq i} D_{jsk} e_{jsk}^*$$

Again, we may check that (i) and (vii)-(x) imply optimality of e_{ijk}^*, and therefore the conditions for an equilibrium are satisfied.

For the USSR, the net revenue from exports and imports is $E_s - M_s$. For product k, the social cost, when exports (or imports) result in a consumption level c_{sk}, is $\int_{0+}^{c_{sk}} P_{sk}(c)dc$. Note that this is a negative and monotonically increasing function of c_{sk} ; i.e., the higher the consumption the lower the social cost. The problem of maximizing the trade surplus is to

$$\text{maximize} \int_0^{c_{sk}} P_{sk}(c)dc + E_s - M_s$$

subject to

$$c_s + \sum_j (e_{sj} - e_{js}) = y_s^0$$

$$L_{sj} \leq e_{sj} \leq U_{sj}$$

$$L_{js} \leq e_{js} \leq U_{js}$$

$$E_s = \sum_{j,k} (\pi_{jk}^* - D_{sjk}) e_{sjk} \geq E_s^0$$

$$M_s = \sum_{j,k} (\pi_{jk}^* + D_{jsk}) e_{jsk} \leq M_s^0$$

One can readily check that the equilibrium conditions imply optimality to this problem. Varying the "marginal penalty" π_{sk}^0 (see section *Consumption*), one can study different trade policies. For instance, choosing π_{sk}^0 sufficiently large, we can consider a policy oriented mainly to the satisfaction of desirable (planned) consumption. Choosing π_{sk}^0 sufficiently small, the most profitable export-import policies can be analyzed.

Consider next the trade involving the USSR. From Dykstra and Kallio (1984) we have for trade between *other* regions that if a trade flow e_{ijk}^* is on its lower bound, then

$$\pi_{jk} - \pi_{ik} = D_{ijk} \tag{18}$$

For trade involving the USSR, this can be rewritten as follows:

$$\pi_{jk} - \pi_{sk} \leq D_{sjk} - \pi_k^* \xi_s \qquad \text{(Soviet exports)}$$

$$\pi_{sk} - \pi_{jk} \leq D_{jsk} + \pi_k^* \psi_s \qquad \text{(Soviet imports)}$$

If trade actually takes place, but inertia constraints are nonbinding, then these hold as equalities. Thus, if the export revenue requirement is binding the Soviets may be exporting even if the penalty π_{sk} is higher than the net revenue $\pi_{jk} - D_{sjk}$. Similarly, if the import budget is binding, the Soviets may import even if the penalty π_{sk} of decreasing consumption would be lower than the gross expenditure $\pi_{jk} + D_{jsk}$.

ALTERNATIVE PENALTY FUNCTIONS

It will be interesting to consider some alternatives for the Soviet model which more explicitly reflect assumptions (a) and (e) of the Introduction. Let

$$\Delta_{sk} = w_k \frac{c_{sk}^0 - c_{sk}}{c_{sk}^0} \tag{19}$$

where c_{sk}^o is the desired (or planned) consumption of product k, c_{sk} is attainable consumption, and w_k describes the "significance" of product k. Thus Δ_{sk} is a weighted relative deficiency of not meeting the target c_{sk}^0; its value is 0 if the target is met.

The trade policy of the USSR is then defined by the following model:

$$\min \Delta \tag{20}$$

subject to

$$\Delta \geq 0, \ \Delta \geq \Delta_{sk},$$

$$c_s + \sum_j (e_{sj} - e_{js}) = y_s^o$$

$$L_{sj} \leq e_{sj} \leq U_{sj}$$

$$L_{js} \leq e_{js} \leq U_{js}$$

$$E_s = \sum_j \pi_j^* e_{sj} \geq E_s^o$$

$$M_s = \sum_j \pi_j^* e_{js} \leq M_s^o$$

This formulation minimizes the largest weighted relative deficiency Δ_{sk} over all products. If Δ is equal to zero, then all targets can be met and the next step is to

$$\max (E_s - M_s) \tag{21}$$

subject to the same constraints except the first line where the equalities

$$\Delta_{sk} = 0$$

have to be used. In other words, in the second step we maximize the net trade revenue subject to the additional requirement that all consumption targets c_{sk}^0 are satisfied.

The model (19)–(21) is very simple from the computational viewpoint and reflects the idea of assumption (a): that consumption targets should be satisfied first, after which the trade surplus should be maximized. Unlike the model of the previous section, this model does not permit the importation of products (even if they are cheap) if target levels are attained.

A slight modification of the above results when the objective function (20) is replaced by

$$\min \sum \Delta_{sk} \tag{20'}$$

That is, the new objective function is a weighted sum of relative deficiencies. Again, the minimization is subject to the requirement that consumption cannot exceed the target levels c_{sk}^0. If all targets are attainable, then the second step should be taken as described above.

In addition to these two alternatives is the well-known goal programming approach for a two-criteria planning problem. The two objectives are: first, to minimize the maximum weighted relative deficiency in meeting the consumption goals, and second, to maximize the trade revenue. With a suitable choice of parameters in the model (19)–(21), the two approaches are in fact equivalent planning models.

For the demonstration runs described in the following section, objective function (20') was used.

DEMONSTRATION RUNS WITH THE SOVIET MODULE

To test the implementation of the Soviet module formulated in this paper, the module was incorporated into the six-region preliminary version of the GTM reported by Dykstra and Kallio (1984). In the Dykstra-Kallio model, the USSR had been included in the large region referred to as the "rest of the world." For the present runs, then, the "rest of the world" was redefined to exclude the Soviet Union, and the USSR was added as a seventh region. Production, consumption, and trade data for the "rest of the world" were adjusted to account for the removal of the USSR from that region. Raw material costs, conversion factors, production costs, and trade costs, however, were assumed to be unchanged. The data used to describe the forest resources, forest industries, and trade among the remaining regions (Nordic countries, Western Europe, USA, Canada, and Japan) were identical to those described in Dykstra and Kallio (1984).

Table 5 summarizes the conversion-factor data used in the Soviet module. This table is essentially an extract from the mathematical programming matrix of the Soviet module as it is included in the seven-region preliminary GTM. Rows represent both intermediate and final products, and columns represent conversion activities from raw materials or intermediate products into final products. Note that in the Soviet module there is exactly one column for each conversion activity. In the market-economy modules, conversion activities are represented by two or three columns, as discussed in Section 4.3 (pages 17–20) of Dykstra and Kallio (1984). Newsprint, for instance, may be produced by any of three technologies: older mills, modern mills, or state-of-the-art mills (new investments). In the Soviet module we do not segregate technologies in this way because of the fact that production levels of all final products are exogenously given. Therefore only one technology is used to represent each conversion activity. For a similar reason trees are not segregated into "large trees" and "small trees" as with the market-economy regions.

As a comparison between the results of the six-region preliminary model reported by Dykstra and Kallio (1984) and the results when the USSR is incorporated as a seventh region, we made computer runs corresponding to the base scenarios for the years 1980 and 2000 and described on pages 23–34 and 41–47 of Dykstra and Kallio (1984). Data for the runs were identical to those used in the Dykstra-Kallio tests, except for the adjustments to the "rest of the world" region made to account for the removal of the USSR from that region, and the new data used for the Soviet module.

Data used to fix production levels and consumption targets for the USSR in the test runs are summarized in Table 6. Production levels and consumption targets for 1980 are based on actual data. We made the conservative assumption that timber supplies in the Soviet Union will not increase substantially by the year 2000. It is difficult to justify this assumption as anything other than an interesting scenario possibility; data from Vorobjov (1982) suggest that even

TABLE 5. Conversion factors (m^3/m^3, m^3/t, or t/t) for the Soviet module of the preliminary version of the GTM. A negative number implies consumption of the resource represented by the row in which the number occurs, whereas a positive number implies production.

	Raw materials		Production					
	Trees	Recycled paper	Sawnwood	Panels	Pulp	Newsprint	Printing paper	Packaging paper
Logs	0.426		−1.373	−1.100				
Pulpwood + Chips	0.088		0.057	0.100	−4.700	−1.500	−0.250	−0.700
Sawnwood			1.0					
Panels				1.0				
Pulp					1.0	−0.220	−0.760	−0.330
Newsprint						1.0		
Printing paper							1.0	
Packaging paper								1.0
Recycled paper		1.0						−0.500

in 1980 the allowable harvest volume was about 638 million m^3 as compared to the actual volume felled of 357 million m^3. Whether or not the additional volume available can actually be exploited, however, depends largely on the success of efforts to improve transportation infrastructure, such as the BAM Railway project currently underway in Siberia (Iakunin 1984). Final-product levels for 2000 were calculated from the regression equations in Table 3 and can be read off the curves in Figures 2–6. It should be noted that Figure 2 and Table 6 show sawnwood production in the USSR declining significantly between 1980 and 2000. This is due to the extrapolation of a recent trend in which other forest products production and roundwood exports have increased at the expense of sawnwood production.

Consumption targets for the year 2000 are based on a general assumption that consumption of forest products in the Soviet Union should increase by approximately 2% annually from 1980. Some adjustments were made to the projected consumption levels calculated in this way, based on observations of historical trends in consumption. As an example, we expect sawnwood consumption in the USSR to remain stable or decline somewhat by the year 2000 because of substitution by non-wood products (Iakunin 1984). The results are the consumption targets shown in the final column of Table 6.

All production costs are treated in the Soviet module as though they are zero. This is because production of all final products is exogenously given and the "cost" actually used to evaluate solutions from the point of view of the Soviet Union is the penalty associated with deviations from target consumption levels, rather than production cost. Similarly, the marginal cost of harvesting trees is also treated as zero (rather than being an increasing function of the volume harvested, as in the market-economy regions). Therefore an upper bound equal to the estimated maximum annual timber removals in the USSR must be set on the "trees" variable, as indicated in Table 6.

TABLE 6. Exogenously fixed USSR production levels and consumption targets for the test runs with the Soviet module, 1980 and 2000. Units are mill. m^3 or mill. tons.

Product	Production levels		Consumption targets	
	1980	2000	1980	2000
Trees*	356.6*	360.0*	–	–
Sawnwood	98.1	77.0	95.0	85.0
Panels	10.5	20.2	9.6	19.1
Pulp*	5.7*	11.1*	–	–
Newsprint	1.5	2.2	1.6	2.1
Printing paper	5.3	7.8	6.0	7.7
Packaging	3.5	5.7	3.4	5.4
Recycling paper*	2.2*	3.3*	–	–

* Raw materials or intermediate products which are consumed within the forest sector. There are no consumption targets for these products, and production figures given for these products are *upper limits* used in the model, rather than fixed production levels as for other products. As used here, "Trees" refers to *fellings*; i.e., the volume of trees felled.

In the six-region model runs, Dykstra and Kallio (1984) set lower bounds on trade variables for 1980 at approximately 80% of the actual trade flows, and upper bounds at about 200% of the actual. We generally followed this procedure for the Soviet module, except that we restricted total exports of each product from the USSR to be less than 10% of production, and stipulated that about half of these exports should be to other CMEA* countries (which are incorporated in the "rest of the world" region). Exceptions to this rule were made for logs and pulpwood, two products for which special long-term agreements exist between the USSR and Japan. Our interpretation of these agreements is that about 75% of the total exports of logs and pulpwood would go to Japan, both in 1980 and in 2000.

The Soviet module requires a lower bound on export revenues (Eq. 12) and an upper bound on import expenditures (Eq. 13). For 1980 we calculated these bounds using, for each category of forest product, the actual export quantity and average unit value of exports (for the lower bound on export revenues) and the import quantity and average unit value of imports (for the upper bound on import expenditures). Then, assuming that the policy of the USSR would be to increase earnings from exports and reduce its dependency on imports, we postulated that the lower bound on export revenues would *increase* by 2% annually and that the upper bound on import expenditures would *decrease* by 2% annually. For 1980 and 2000 we thus derived lower bounds on export revenues of $2929 million and $4352 million, respectively. Upper bounds on import expenditures were $1452 million and $977 million, respectively.

The final special requirement of the Soviet module is the specification of the penalty function. For these test runs, we decided to use the formulation in Eqs. (19), (20'), and (21) rather than the Cobb-Douglas form given in Eq. (7). To find an expression for calculating appropriate values for the weights w_k in Eq. (19), differentiate Eq. (19) with respect to attainable consumption c_{sk}. This derivative is equal to the price, π_{sk}, assuming that target consumption levels are *not* attained. Therefore,

$$w_k = \pi_{sk} c_{sk}^0$$

Then, given target consumption levels and prices, we can calculate the weights w_k. In the context of the maximization problem specified by Eqs. (8)–(13), we maximize the *negative* of Eq. (19); therefore the weights w_k are positive. The calculated weights for the Soviet Union in 1980 and 2000 are given in Table 7. For 1980, we used observed consumption levels with average unit values as a surrogate for price. To calculate the weights for 2000, we assumed that prices of forest products traded by the Soviet Union would increase from 1980 at annual rates varying from 0.5 to 1.5%.

* CMEA = Council for Mutual Economic Assistance, an organization comprising Bulgaria, Cuba, Czechoslovakia, the German Democratic Republic, Hungary, Mongolia, Poland, Rumania, Vietnam, and the USSR.

TABLE 7. Penalty-function weights w_k for the Soviet module, 1980 and 2000. Note that, for all products, the ratio of the weight in 2000 divided by the weight in 1980 is approximately a constant.

Product	1980	2000
Sawnwood	17,100	31,000
Panels	2,976	6,870
Newsprint	640	1,130
Printing Paper	4,560	6,545
Packaging	1,700	2,975

RESULTS AND DISCUSSION

Tables 8 and 9 summarize the consumption and price results for the seven-region model runs with the USSR as a separate region. Except for the fact that the consumption levels and price information for the Soviet Union are made explicit, these results are largely unchanged from Dykstra and Kallio (1984). The prices of sawnwood and panels in 1980 are slightly lower in this analysis than in the Dykstra-Kallio run, and consequently consumption quantities are marginally higher. The maximum price difference, however, is only about 11% with a much smaller maximum consumption difference.

In general, this trend is also exhibited by the consumption and price results for the year 2000. As compared to the Dykstra-Kallio run, prices are slightly lower, especially for mechanical wood products, and consumption is marginally higher. However, there is one exception to this. In segregating the USSR from the "rest of the world," we have uncovered an apparent decline in the production of sawnwood in the Soviet Union (Figure 2). Extrapolating this trend, we have fixed sawnwood production for the year 2000 at 77 million m^3 (Table 6), or almost 22% less than the production in 1980. Other things being equal, we would expect the price of sawnwood in the USSR to rise and imports to increase in order to satisfy demand. However, we have also imposed a strict upper bound on the total expenditures for imports. This upper bound ($977 million) prevents all but a small quantity of sawnwood from being imported into the USSR. By comparison with the Dykstra-Kallio run, then, the projected consumption of sawnwood in the USSR in the year 2000 is much reduced when the USSR is treated explicitly as a separate region, even though the price of sawnwood rises only slightly.

We do not claim that this result is necessarily a very likely occurrence in the year 2000. Our projection of the rate of decline of sawnwood production, for example, may be too pessimistic; or, the upper limit on expenditures for imports may be far too limiting. However, the fact that our analysis has uncovered this possibility provides us with a motivation to study the situation more carefully. Indeed, the possibility of such a development could not have been identified at all if the USSR had not been treated explicitly as a separate region. A primary reason for developing a more disaggregated Global Trade Model is that it will permit the consideration of situations which a highly aggregated model would tend to obscure.

TABLE 8. Consumption of final products in 1980 and 2000, with comparisons for 1980 from FAO (1982). Units for sawnwood and panels are mill. m^3; for other products, mill. tons.

Region		Sawnwood	Panels	Newsprint	Printing paper	Packaging paper
Northern	1980	11.6	3.6	0.7	1.2	2.3
Europe	(FAO 1980)	(11.4)	(3.5)	(0.7)	(1.2)	(2.3)
	2000	14.2	4.8	1.0	1.8	3.0
Western	1980	65.5	24.0	5.1	11.4	14.6
Europe	(FAO 1980)	(62.6)	(24.0)	(5.0)	(11.3)	(14.6)
	2000	78.3	31.7	6.3	16.8	20.3
USA	1980	87.7	26.4	10.9	14.6	32.7
	(FAO 1980)	(92.4)	(27.4)	(10.6)	(14.2)	(32.3)
	2000	97.4	33.3	11.0	22.5	40.4
Canada	1980	13.5	4.0	0.9	1.0	2.0
	(FAO 1980)	(14.1)	(4.2)	(0.9)	(1.0)	(2.0)
	2000	15.8	5.5	1.1	1.8	2.7
Japan	1980	45.7	10.7	2.7	4.0	9.6
	(FAO 1980)	(42.6)	(10.4)	(2.7)	(3.9)	(9.6)
	2000	54.9	13.8	3.9	7.2	15.8
USSR	1980	90.9	9.5	1.1	5.2	3.3
	(FAO 1980)	(91.4)	(9.8)	(1.2)	(4.8)	(3.3)
	2000	77.0	16.3	1.9	7.5	5.3
Rest of	1980	118.4	21.7	5.6	6.3	8.6
the World	(FAO 1980)	(114.2)	(21.5)	(5.6)	(5.6)	(8.7)
	2000	180.1	72.4	10.5	19.0	20.5

TABLE 9. Prices of final products in 1980 and 2000, with comparisons for 1980 based on average unit values from FAO (1982). Units for sawnwood and panels are $\$/m^3$; for other products, $/ton.

Region		Sawnwood	Panels	Newsprint	Printing paper	Packaging paper
Northern	1980	210	296	485	710	556
Europe	(FAO 1980)	(230)	(320)	(470)	(720)	(550)
	2000	171	367	482	626	565
Western	1980	223	338	533	764	586
Europe	(FAO 1980)	(250)	(345)	(560)	(845)	(580)
	2000	184	371	530	777	602
USA	1980	154	309	428	611	413
	(FAO 1980)	(160)	(280)	(430)	(625)	(450)
	2000	158	369	439	618	451
Canada	1980	149	316	370	649	455
	(FAO 1980)	(145)	(275)	(400)	(640)	(450)
	2000	144	354	365	650	493
Japan	1980	201	341	481	753	530
	(FAO 1980)	(230)	(375)	(510)	(800)	(520)
	2000	176	377	514	790	582
USSR	1980	180	310	400	760	500
	(FAO 1980)	(170)	(300)	(425)	(750)	(480)
	2000	230	360	538	850	553
Rest of	1980	177	287	449	781	465
the World	(FAO 1980)	(200)	(315)	(425)	(700)	(450)
	2000	179	358	517	793	485

The remaining results from the runs with the seven-region model are so similar to the results from the Dykstra-Kallio runs that it seems needlessly repetitious to describe them in detail here. For reference, Tables 10–12 summarize the results of both the 1980 and 2000 runs when the Soviet Union is treated as a separate region. Careful comparison of these tables with the results summarized by Dykstra and Kallio (1984) will show that the runs are generally quite comparable. The most notable differences are those in the trade flows for the year 2000, where the special trade restrictions implemented in the Soviet module have the effect of moderating some of the trade flows.

TABLE 10. Consumption (mill. m^3, mill. t) and prices ($/$m^3$, $/t) of logs, pulpwood, and pulp with comparisons for 1980 from FAO (1982).

Region		Consumption			Price		
		Logs	Pulp-wood	Pulp	Logs	Pulp-wood	Pulp
Northern Europe	1980	50.9	53.5	3.0	54	39	449
	(FAO 1980)	(51.1)	(62.4)	(3.3)	(55)	(45)	(480)
	2000	51.4	52.3	4.1	51	44	431
Western Europe	1980	70.9	36.5	7.2	73	41	464
	(FAO 1980)	(70.8)	(49.8)	(10.1)	(70)	(50)	(520)
	2000	72.9	50.5	8.3	62	48	470
USA	1980	170.3	191.3	17.7	39	23	375
	(FAO 1980)	(171.1)	(164.0)	(19.1)	(40)	(20)	(465)
	2000	226.0	302.6	30.9	31	25	381
Canada	1980	116.6	63.9	4.1	30	22	390
	(FAO 1980)	(116.5)	(72.9)	(2.0)	(30)	(24)	(465)
	2000	122.0	67.8	5.4	30	22	389
Japan	1980	56.0	28.9	4.2	79	37	408
	(FAO 1980)	(57.6)	(31.3)	(5.7)	(100)	(58)	(530)
	2000	79.5	38.1	6.4	55	49	480
USSR	1980	146.2	32.8	5.5	67	15	488
	(FAO 1980)	(145.6)	(30.0)	(5.4)	(50)	(20)	(470)
	2000	128.0	61.6	8.3	98	98	460
Rest of the World	1980	213.6	26.3	3.9	36	19	491
	(FAO 1980)	(228.7)	(20.5)	(2.2)	(40)	(20)	(470)
	2000	360.0	77.4	10.3	37	22	497

TABLE 11. Production of final products (mill. m^3, mill. t) with comparisons for 1980 from FAO (1982).

Region		Sawnwood	Panels	Newsprint	Printing paper	Packaging paper
Northern Europe	1980	23.9	3.6	2.9	4.3	3.0
	(FAO 1980)	(23.9)	(4.6)	(3.7)	(3.5)	(5.4)
	2000	23.9	4.8	2.9	7.6	2.9
Western Europe	1980	39.6	21.3	1.5	8.3	11.7
	(FAO 1980)	(39.6)	(20.9)	(2.3)	(10.4)	(11.6)
	2000	39.6	31.7	4.1	8.8	14.1
USA	1980	75.3	27.4	4.1	16.3	38.9
	(FAO 1980)	(75.3)	(26.2)	(2.3)	(13.7)	(35.4)
	2000	104.3	30.6	9.0	32.0	47.1
Canada	1980	41.9	4.8	10.6	1.9	3.1
	(FAO 1980)	(41.9)	(4.8)	(8.6)	(1.5)	(2.7)
	2000	41.9	8.2	6.9	3.9	5.2
Japan	1980	37.1	8.9	2.7	3.2	8.9
	(FAO 1980)	(37.1)	(10.3)	(2.7)	(4.1)	(9.5)
	2000	54.9	10.7	1.9	5.5	12.8
USSR	1980	98.1	10.4	1.5	5.3	3.5
	(FAO 1980)	(98.1)	(10.5)	(1.5)	(5.3)	(3.5)
	2000	77.0	20.2	2.2	7.8	5.7
Rest of the World	1980	117.5	23.5	3.6	4.3	3.9
	(FAO 1980)	(112.5)	(23.9)	(3.5)	(3.9)	(7.4)
	2000	176.1	71.6	8.7	10.9	20.3

TABLE 12. Annual bilateral trade flows (mill. m^3, mill. ton). Upper figures in each table are from the 1980 run, lower figures from the 2000 run. Total exports and imports are given in comparison with the FAO figures for 1980. Regions: 1 = Northern Europe, 2 = Western Europe, 3 = USA, 4 = Canada, 5 = Japan, 6 = USSR, 7 = Rest of the World.

(a) Logs

	1	2	3	4	5	6	7	Total Exports	FAO 1980
1		1.0					0.3	1.3	1.2
								.0	
2								.0	1.7
								.0	
3		1.0		1.0	11.5		1.1	14.6	14.7
		6.0			2.2			8.2	
4	1.0	1.0	0.3		1.2			3.5	1.1
		4.0			12.0			16.0	
5								.0	.0
								.0	
6	0.4				5.1		0.5	6.0	6.1
					16.0		2.3	18.3	
7	1.4	5.2			25.6	0.2		32.4	30.1
	3.1	10.0			38.8	10.0		62.0	
Total Imports	2.8	8.2	0.3	1.0	43.4	0.2	1.9	57.8	54.9
	3.1	20.0	.0	.0	69.1	10.0	2.3	104.5	
FAO 1980	1.4	10.7	0.6	2.0	36.6	.0	3.6	54.9	

(b) Pulpwood

	1	2	3	4	5	6	7	Total Exports	FAO 1980
1							0.1	0.1	2.9
						4.3		4.3	
2	0.2						0.1	0.3	6.5
								.0	
3	0.4			0.3	4.8			5.5	6.9
		5.5			6.6			12.1	
4	0.1	0.2	1.2		0.4		0.2	2.1	3.0
		2.0			4.0			6.0	
5								.0	.0
								.0	
6	2.2	0.9			1.0			4.1	4.8
							0.4	0.4	
7	5.2	5.5			10.5			21.2	15.3
	2.5	2.5			10.0	2.5		17.5	
Total Imports	8.1	6.6	1.2	0.3	16.7	.0	0.3	33.3	39.4
	2.5	10.0	.0	.0	20.6	6.8	0.4	40.3	
FAO 1980	8.1	10.1	2.1	0.7	13.6	.0	4.8	39.4	

(c) Sawnwood

	1	2	3	4	5	6	7	Total Exports	FAO 1980
1		12.7 14.7					2.7	15.4 14.7	13.3
2							0.9	0.9 .0	6.2
3	1.0	0.2 12.0		0.1	3.0		1.0	5.2 12.0	4.6
4	1.0 5.0	2.8 12.0	17.7 5.1		5.2		1.8 4.0	28.5 26.1	29.0
5							.0	.0 .0	.0
6	0.9	3.1			0.2		3.0	7.2 .0	2.7
7	0.2	8.0			0.2			8.4 .0	10.2
Total Imports	3.1 5.0	26.8 38.7	17.7 5.1	0.1 .0	8.6 .0	.0 .0	9.4 4.0	65.6 52.8	66.0
FAO 1980	1.8	23.4	22.2	0.7	4.9	.0	9.8	62.8	

(d) Panels

	1	2	3	4	5	6	7	Total Exports	FAO 1980
1		0.2					0.2	0.4 .0	1.9
2	0.1						0.2	0.3 .0	5.1
3		0.6			1.0		0.3	1.9 .0	1.0
4		0.3	 2.7		0.8			1.1 2.7	0.8
5			0.1					0.1 .0	0.1
6	0.2	0.3			 3.1		0.4 0.8	0.9 3.9	0.1
7	0.1	1.6	0.9	0.2	0.2			3.0 .0	6.8
Total Imports	0.4 .0	3.0 .0	1.0 2.7	0.2 .0	2.0 3.1	.0 .0	1.1 0.8	7.7 6.6	15.8
FAO 1980	0.7	8.2	2.1	0.2	0.3	.0	3.8	15.3	

(e) Pulp

	1	2	3	4	5	6	7	Total Exports	FAO 1980
1		2.4			0.1	0.1	1.1	3.7	3.7
		1.4						1.4	
2							0.2	0.2	1.1
								.0	
3		2.6			0.6		1.2	4.4	2.6
		4.4			3.4		2.1	9.9	
4		0.7	0.9		0.2		0.1	1.8	6.4
		1.5						1.5	
5								.0	0.1
								.0	
6							0.3	0.3	0.1
							2.8	2.8	
7	0.1	0.6	0.2		0.4			1.3	1.2
								.0	
Total Imports	0.1	6.4	1.0	.0	1.2	0.1	2.9	11.7	15.2
	.0	7.3	.0	.0	3.4	.0	4.9	15.5	
FAO 1980	0.2	7.8	3.1	0.1	1.4	0.2	1.7	15.3	

(f) Newsprint

	1	2	3	4	5	6	7	Total Exports	FAO 1980
1		1.9	0.1				1.0	3.0	3.2
		2.0						2.0	
2								.0	0.3
								.0	
3							0.2	0.2	0.2
								.0	
4	0.9	1.2	6.8				0.7	9.6	7.7
	0.2	0.1	2.0		2.0		1.5	5.8	
5								.0	0.1
								.0	
6		0.1					0.3	0.4	.0
							0.3	0.3	
7		0.3						0.3	1.0
								.0	
Total Imports	0.9	3.5	6.9	.0	.0	.0	2.2	13.5	12.5
	0.2	2.1	2.0	.0	2.0	.0	1.8	8.1	
FAO 1980	0.2	3.1	6.6	.0	0.1	.0	2.8	12.8	

(g) Printing paper

	1	2	3	4	5	6	7	Total Exports	FAO 1980
1		2.6 4.0	0.1			0.5	 1.8	3.2 5.8	2.5
2	0.1					0.1	1.0	1.2 .0	2.9
3		1.0 2.0		0.1	0.9 1.5		0.2 6.0	2.2 9.5	0.2
4		0.5 2.0	0.4		 0.1		0.1	1.0 2.1	0.7
5							0.2	0.2 .0	0.2
6		0.1					0.6 0.3	0.7 0.3	.0
7								.0 .0	0.5
Total Imports	0.1 .0	4.2 8.0	0.5 .0	0.1 .0	0.9 1.6	0.6 .0	2.1 8.1	8.5 17.7	7.0
FAO 1980	0.2	3.7	0.7	0.1	.0	.7	1.0	6.7	

(h) Packaging paper

	1	2	3	4	5	6	7	Total Exports	FAO 1980
1		0.5			0.1		1.5	2.1 .0	3.5
2	0.1						1.6	1.7 .0	2.2
3	1.0 0.1	2.0 3.0		0.9 0.5	0.7 3.0		1.7	6.2 6.6	3.3
4		2.0 3.0						2.0 3.0	0.8
5							0.1	0.1 .0	0.1
6	0.2	 0.2					 0.2	0.2 0.4	0.1
7	0.1	0.1						0.2 .0	0.9
Total Imports	1.4 0.1	4.6 6.2	.0 .0	0.9 0.5	0.8 3.0	.0 .0	4.9 0.2	12.5 10.0	10.9
FAO 1980	0.3	5.1	0.2	0.1	0.3	.0	2.2	8.2	

CONCLUDING REMARKS

The module developed in this paper to serve as an abstraction of the forest sector of a centrally planned economy appears to function satisfactorily when incorporated into IIASA's global forest sector model. Results of tests with the preliminary model utilizing data for the Soviet Union suggest that a full-scale model can be developed which will be capable of accurately assessing possible long-term structural changes in the forest sector, for both market economies and centrally planned economies simultaneously.

As in the paper by Dykstra and Kallio (1984), we must emphasize that the numerical results reported here should only be considered illustrative. The global forest sector model as presently configured includes only seven regions, all highly aggregated. Our trials with this model have been designed to determine whether the model is satisfactory in a general, qualitative sense. Specific quantitative results will have to await the development of the full-scale global forest sector model.

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APPENDIX

TABLE 13. Regression models fitted to production data for the USSR (1960–1980). Two or more equations were fitted for each product, and the statistically superior equation was used in the **GTM** to project final-product production for the year 2000 (see Table 3 in the main body of the paper). Current year = 1960 + t, and t_1 = max $\{t-15,0\}$. Numbers in brackets are t-ratios of the associated parameter estimates.

Regression equation	R^2
$LOGS_t = (0.426)ROUNDWOOD_t$ [34.0]	0.9974
$LOGS_t = (0.43211 - 0.0010t + 0.00167t_1)ROUNDWOOD_t$ [22.4] [0.4] [0.5]	0.9974
$SAWNWOOD_t = (0.2962 - 0.0004t)ROUNDWOOD_t$ [75.5] [1.4]	0.9990
$SAWNWOOD_t = (0.2851 + 0.0015t - 0.0045t_1)ROUNDWOOD_t$ [96.9] [4.2] [6.2]	0.9996
$PANELS_t = (0.0026 + 0.0014t)ROUNDWOOD_t$ [5.9] [41.9]	0.9986
$PANELS_t = (0.0030 + 0.0013t + 0.0001t_1)ROUNDWOOD_t$ [4.6] [17.3] [0.9]	0.9986
$PULP_t = (0.0075 + 0.001t)ROUNDWOOD_t$ [13.4] [22.1]	0.9974
$PULP_t = (0.0058 + 0.0012t - 0.0004t_1)ROUNDWOOD_t$ [8.6] [15.2] [3.4]	0.9984
$NEWSPRINT_t = (0.0005)INDUS.ROUNDWOOD_t + (0.1463)PULP_t$ [2.0] [17.2]	0.9964
$NEWSPRINT_t = (0.00132 + 0.00014t)ROUNDWOOD_t$ [20.7] [28.9]	0.9976
$NEWSPRINT_t = (0.00117 + 0.00017t - 0.00006t_1)ROUNDWOOD_t$ [19.5] [23.1] [4.2]	0.9988
$PRINTING_t = (0.0045)INDUS.ROUNDWOOD_t + (0.453)PULP_t$ [12.2] [31.4]	0.9982
$PRINTING_t = (0.0066 + 0.00044t)ROUNDWOOD_t$ [35.4] [29.9]	0.9986
$PRINTING_t = (0.00623 + 0.00050t - 0.00015t_1)ROUNDWOOD_t$ [31.4] [20.4] [3.0]	0.9996
$PACKAGING_t = (0.00218 + 0.00040t)ROUNDWOOD_t$ [11.4] [26.9]	0.9960
$PACKAGING_t = (0.00180 + 0.00047t - 0.00016t_1)ROUNDWOOD_t$ [8.9] [14.0] [3.2]	0.9974

TABLE 14. Abbreviated time series for total roundwood and industrial roundwood. Total roundwood includes all wood in the rough used for commercial purposes. Industrial roundwood excludes fuelwood and charcoal and special tree parts such as roots, stumps, and burls. Source: *Statistika* (1982).

Commodity	1940	1955	1965	1970	1975	1980	1981	1982
Roundwood	247	334	379	385	395	357	358	356
Industrial roundwood	118	212	274	299	313	278	277	273