Working Paper

A PRELIMINARY MODEL OF PRODUCTION, CONSUMPTION AND INTERNATIONAL TRADE IN FOREST PRODUCTS

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Markku Kallio

February 1984
WP-84-14

International Institute for Applied Systems Analysis
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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 consequences 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 other main research activity is a detailed analysis of the forest sector in individual countries. Research on these mutually supporting topics is carried out simultaneously in collaboration between IIASA and the collaborating institutions of the Project.

This paper reports on the Project's preliminary model for analyzing production, consumption, and international trade in forest products. Model formulation and demonstration scenarios are discussed with the intention of instilling confidence in the model's ability to correctly represent macroeconomic principles. Data used for the scenario runs must be considered very tentative however, so that specific quantitative conclusions about long-term trends in the forest sector cannot be drawn. The preliminary model deals with six world regions and nine products. A full-scale version of the model now under development will include more detail on both regions and products, as well as more sophisticated treatment of timber supply, processing capacity expansion, and projection of future demand for wood products.

Markku Kallio
Project Leader
Forest Sector Project

ACKNOWLEDGMENTS

The authors are grateful to Matti Kirjasniemi and Esko Uutela, both from Jaakko Pöyry International Oy, for discussions concerning the model structure, data, and scenarios presented in this paper. The receipt of preliminary data from the following persons is also gratefully acknowledged: David Batten, David Brooks, Trevor Eton, Joldes Muniz Ferreira, Csaba Forgacs, Alfredo Iusem, Allister Moon, Christopher Prins, Risto Seppälä, Birger Solberg, and Philip Wardle.

ABSTRACT

The preliminary version of IIASA's model of production, consumption, and trade in forest products is discussed. The model involves six regions (Northern Europe, Western Europe, USA, Canada, Japan, and the rest of the World) and nine products (sawlogs, pulpwood, sawnwood, panels, pulp, newsprint, other printing and writing paper, packaging paper and board, and recycled paper). The primary purpose of this version is to analyze sensitivity of the model with respect to various parameters and to learn to understand the model behavior in general.

We first review the formulation of the spatial equilibrium model, and then discuss the equilibrium conditions in detail. Subsequent sections describe the preliminary data and two sets of numerical demonstrations. The first set deals with the situation in 1980. A base scenario for model validation is discussed first. Stability of the model with respect to price elasticity parameters for demand is shown. The effect of a change in currency exchange rate is demonstrated. The second set of runs simulates the situation around the year 2000. For the base scenario, we update wood resources, production capacity, and demand for each region. This scenario is compared with high- and zero-growth demand scenarios. The effect of tariffs and changes in timber supply are demonstrated.

Finally, we wish to stress that this preliminary model employs very tentative data. Therefore, one should draw conclusions from the demonstration scenarios with special care.

CONTENTS

A PRELIMINARY MODEL OF PRODUCTION, CONSUMPTION AND INTERNATIONAL TRADE IN FOREST PRODUCTS

by

Dennis Dykstra and Markku Kallio

1. INTRODUCTION

The purpose of this paper is to document the formulation of a preliminary version of the Global Trade Model (GTM) under development by IIASA's Forest Sector Project and to provide a numerical demonstration of the model's capabilities. The preliminary model comprises six regions (Northern Europe, the rest of Western Europe, USA, Canada, Japan and the rest of the world) and nine products (sawlogs, pulpwood, sawnwood, panels, pulp, newsprint, other printing and writing paper, packaging paper and board, and recycled paper). Data have been extracted largely from publications of the United Nations (FAO 1982a, 1982b and 1982c, ECE 1976, 1981 and 1982, UNIDO 1983), and must be considered very tentative. One should therefore draw conclusions from the test runs with special care. The primary purposes of this first version are to analyze the sensitivity of model solutions with respect to various parameters and to obtain a general understanding of the model's behavior. The preliminary model also serves as a vehicle to test alternative solution methodologies. The final version of the model, which will comprise 18 regions and 13 commodities and will be based on improved data gathered from 57 countries and regions worldwide (Dykstra 1983, Kornai 1983), is expected to be ready by the autumn of 1984.

We shall first review the model formulation in Section 2. The basic structure is that given in Kirjasniemi et al. (1983), resulting from early developments of the Project (Salo and Kallio 1982, Kallio 1983, and Buongiorno and Gilless 1983). Some minor modifications resulting from experience with earlier versions have been incorporated. In Section 3 we

discuss the equilibrium conditions in detail. This discussion should help in understanding the basic characteristics of the model solutions. It will also help clarify the definition of certain data parameters; e.g., what cost components should be accounted for in a given cost coefficient. Sections 4-8 deal with two sets of numerical demonstrations. The first set simulates the situation of 1980. A version involving trade inertia constraints represents the real world situation in that year. The effect of varying some uncertain key parameters, the price elasticity parameters for demand, is illustrated. The effect of a change in exchange rates as compared to the US dollar is demonstrated as well. The second set of runs simulates the situation around the year 2000 under various assumptions. For the base run we project timber supply, production capacity, and demand to provide an economic environment commensurate with the broad assumptions outlined in FAO (1982b). The solution is compared with high and low demand scenarios. The effects of trade-flow inertias, tariffs, and changing wood resources are also demonstrated.

It is important to remember that the data upon which this preliminary model rests are very tentative. No specific quantitative conclusions can thus be drawn from the model results; rather, the focus of the exercise is on the determination of whether the model itself is appropriate for modeling the forest sector of the global economy. Specific conclusions about possible long-term structural changes in the forest sector will have to await the development of the full-scale **GTM**.

2. MODEL FORMULATION

We shall consider a static (one-year) model for which the parameters may be set to correspond to a specific point in time. The time subscript t is therefore normally omitted in this discussion.

2.1. Regional Subdivision and Product Classification

The preliminary **GTM** comprises six regions and nine product categories, as shown in Table 1. Also shown for comparison are the regions and product categories for the full-scale **GTM**.

2.2. Production

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. After describing the general structure of the production model, we discuss each type of production activity separately.

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, is a resource (or available capacity) upper limit K_{im} so that

$$y_i \leq K_i \tag{1}$$

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 for the same

Table 1. Regional and product definitions in the preliminary model and **GTM**.

Regions	
Preliminary Model	Further Refinement in Full-Scale **GTM**
Northern Europe	Finland
	Sweden
Western Europe	Western Europe
USA	USA-East
	USA-West
Canada	Canada-East
	Canada-West
Japan	Japan
Rest of the World	Brazil
	Rest of Latin America
	USSR, European
	USSR, Asian
	Rest of Eastern Europe
	Africa
	China
	ASEAN countries
	Rest of Asia
	Australia and New Zealand
Product Definitions	
Preliminary Model	Further refinement in Full-Scale **GTM**
Logs	Coniferous logs
	Non-coniferous logs
Pulpwood	Pulpwood
	Fuelwood
Sawnwood	Coniferous sawnwood
	Non-coniferous sawnwood
Panels	Panels
Pulp	Pulp
Newsprint	Newsprint
Other printing & writing papers	Other printing & writing papers
	Household & sanitary papers
Packaging paper & boards	Packaging paper & boards
Recycled paper	Recycled paper

commodity. The marginal cost Q_{im} is assumed to be constant 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 is assumed to be proportional to newsprint consumption during preceding years.

A harvesting activity m is assumed to yield logs and pulpwood in fixed 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. No explicit upper limit may be 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 stockpiling 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.

2.3. 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 nonnegative parameters.

2.4. Consumption

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

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

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 other commodities, 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 is the level parameter for the demand curve.

2.5 Solution Principle

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. Given prices π_{ik} for each region i and commodity k, profit maximization results in a certain supply of commodities in each region. If, for all i and k, such supply equals the demand as defined by the consumption function, then π_{ik} is an *equilibrium* price. As will be shown in Section 3, such an equilibrium can be obtained as a solution of the following optimization problem (Samuelson, 1952): Find c_i, y_i and e_{ij}, for all i and j, to

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

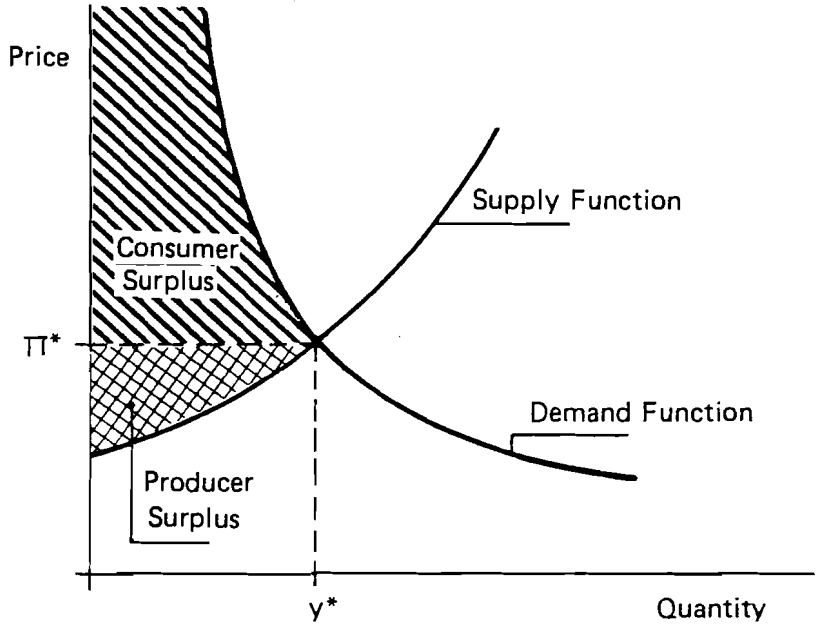
subject to

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

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

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

The objective function (8) is the total consumer and producer surplus. The maximization of this total identifies the point at which the demand and supply are in balance, thus providing the equilibrium price and consumption quantity. The single-producer and single-consumer case has been illustrated in Figure 1. (In our model, the supply function is only implicitly represented, so it is not possible to directly solve for its intersection with the demand function.) 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).



y* = Equilibrium Quantity
Π * = Equilibrium Price

Figure 1. Maximization of consumer and producer surplus to determine equilibrium price and consumption in period *t*.

3. ANALYSIS OF EQUILIBRIUM SOLUTIONS

We shall employ standard optimization theory to show that an optimal solution for (8)-(11) 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). 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)-(11) 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. The optimality conditions for (8)-(11) may then be stated as shown in Table 2.

To show that an optimal solution is an equilibrium, let π_{ik} be the price of commodity k in region i, 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 trading agencies (one for each commodity k). 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.

Table 2. 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,m
(iv)	$(\pi_i A_{im} - Q_{im}(y_{im}^*) - \mu_{im}) y_{im}^* = 0$	for all i,m
(v)	$\mu_{im} \geq 0$	for all i,m
(vi)	$\mu_{im}(K_{im} - y_{im}^*) = 0$	for all i,m
(vii)	$-D_{ijk} - \pi_{ik} + \pi_{jk} - \delta_{ijk} \leq 0$	for all i,j,k
(viii)	$(-D_{ijk} - \pi_{ik} + \pi_{jk} - \delta_{ijk})(e_{ijk}^* - L_{ijk}) = 0$	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

According to (ii) in Table 2 the price π_{ik} and consumption c^*_{ik} are clearly in balance. For producer m in region i, the problem of profit maximization is to find y_{im} to

$$\text{maximize } \pi_i A_{im} y_{im} - \int_0^{y_{im}} Q_{im}(y)dy \tag{12}$$

$$\text{s.t. } 0 \le y_{im} \le K_{im}. \tag{13}$$

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. For a trading agency of commodity k in region i, the profit maximization problem is to find e_{ijk}, for all j, to

$$\text{maximize } \sum_j (\pi_{jk} - \pi_{ik} - D_{ijk}) e_{ijk} \tag{14}$$

$$\text{s.t. } L_{ijk} \le e_{ijk} \le U_{ijk} \tag{15}$$

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

We shall now analyze the optimality conditions in more detail.† For the production sectors m, μ_{im} is the marginal value of capacity m. Conditions (v) and (vi) imply that $\mu_{im} = 0$ if $y_{im} < K_{im}$; in other words, the marginal value is zero if capacity is underutilized. Otherwise μ_{im} is the maximum amount which production sector m would be willing to pay for an extra unit of similar capacity.

If $y^*_{im} > 0$, then conditions (iii) and (iv) imply

$$\mu_{im} = \pi_i A_{im} - Q_{im}(y^*_{im}) \tag{16}$$

Thus, if production activity m is employed, then the marginal value of capacity is the marginal profit. Combining the above, if activity m is utilized but not fully, then the marginal profit of production is zero.

On the other hand, if $y^*_{im} = 0$, then also $\mu_{im} = 0$ and by (iii)

$$Q_{im}(0) - \pi_i A_{im} \ge 0 \tag{17}$$

is the minimum marginal subsidy required to activate production sector m.

For the trading sector k in region i, δ_{ijk} is the marginal value associated with the relaxation of trade inertia upper bound U_{ijk}. Conditions (ix) and (x) imply that for a non-binding upper bound, $\delta_{ijk} = 0$. Conditions (vii)-(viii) imply that if a flow e^*_{ijk} exceeds its lower bound L_{ijk} then

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

† In order to simplify the discussion, we assume primal nondegeneracy. In this case the dual variables indicate marginal values. If the nondegeneracy assumption does not hold, then the dual variables only yield upper bounds on marginal values.

i.e., δ_{ijk} is the marginal profit from trade. This may be interpreted as the maximum tolerable tariff or as a maximum marginal cost of profitable investment for expanding marketing opportunities in region j. Combining the above, if a trade flow falls *between* its upper and lower bounds, then

$$\pi_{jk} - \pi_{ik} = D_{ijk} \tag{19}$$

i.e., the price difference between regions i and j is the transportation cost. If the trade flow e^{*}_{ijk} is on its lower bound L_{ijk}, then $\delta_{ijk}=0$ and by (vii),

$$\pi_{jk} - \pi_{ik} \leq D_{ijk} \tag{20}$$

i.e., the price difference is *at most* equal to the transportation costs. In this case $D_{ijk} - \pi_{jk} + \pi_{ik}$ may be interpreted as a minimum subsidy required to activate trade flow ijk.

4. DATA USED IN THE PRELIMINARY MODEL

4.1 Consumption

Consumption here refers to the use of forest products outside of the forest sector; i.e., sawnwood used for building construction, paper for the information sector, household consumption of paper products, etc. Consumption of intermediate forest products (i.e., roundwood and pulp) outside the forest sector is assumed to be negligible compared to production of these commodities. Our reference values for price and quantity of consumption are given in Tables 3 and 4.

For all of our scenarios for 1980 the consumption functions were defined so that for the reference price, the computed consumption equals the consumption reference value. The basic set of price elasticities is given in Table 5. They are based on a number of sources, including Adams and Haynes (1980), Buongiorno (1978), ECE (1983), Jaakko Pöyry International (1983), and McKillop (1983), as well as on private communications and our judgment. These elasticities were used in all except two scenarios (in which the model sensitivity with respect to these parameters was tested).

Let π and c denote price and consumption, respectively, and π_0 and c_0 the reference values in 1980. If $-1/\gamma$ is the price elasticity then

$$\pi/\pi_0 = (c/c_0)^{-\gamma} \qquad (21)$$

The slope of relative price π/π_0 with respect to relative consumption c/c_0 at $c = c_0$ is equal to $-\gamma$. Two examples of these functions corresponding to price elasticities equal to $-.1$ and $-.5$ (i.e., γ equal to 10 and 2) have been plotted in Figure 2.

Table 3. Reference values for average price π_0 ($/m^3, $/ton) in 1980. Main source: FAO (1982a and 1982c).

Region	Sawn-wood	Panels	News-print	Printing paper	Packaging paper
Northern Europe	230	320	470	720	550
Western Europe	250	345	560	845	580
USA	160	280	430	625	450
Canada	145	275	400	640	450
Japan	230	375	510	800	520
Rest of the World	200	315	425	700	450

Table 4. Reference values for annual consumption c_0 (mill. m^3, mill. ton) in 1980, based on FAO (1982a).

Region	Sawn-wood	Panels	News-print	Printing paper	Packaging paper
Northern Europe	11.4	3.5	0.7	1.2	2.3
Western Europe	62.6	24.0	5.0	11.3	14.6
USA	92.4	27.4	10.6	14.2	32.3
Canada	14.1	4.2	0.9	1.0	2.0
Japan	42.6	10.4	2.7	3.9	9.6
Rest of the World	205.6	31.3	6.8	10.4	12.0
Total	428.7	100.8	26.7	42.0	72.8

Table 5. The basic set of price elasticity coefficients for consumption.

Region	Sawn-wood	Panels	News-print	Printing paper	Packaging paper
Northern Europe	−.20	−.20	−.20	−.05	−.05
Western Europe	−.40	−.30	−.30	−.10	−.10
USA	−.60	−.40	−.35	−.15	−.15
Canada	−.45	−.40	−.30	−.12	−.12
Japan	−.40	−.30	−.30	−.15	−.15
Rest of the World	−.30	−.10	−.15	−.05	−.06

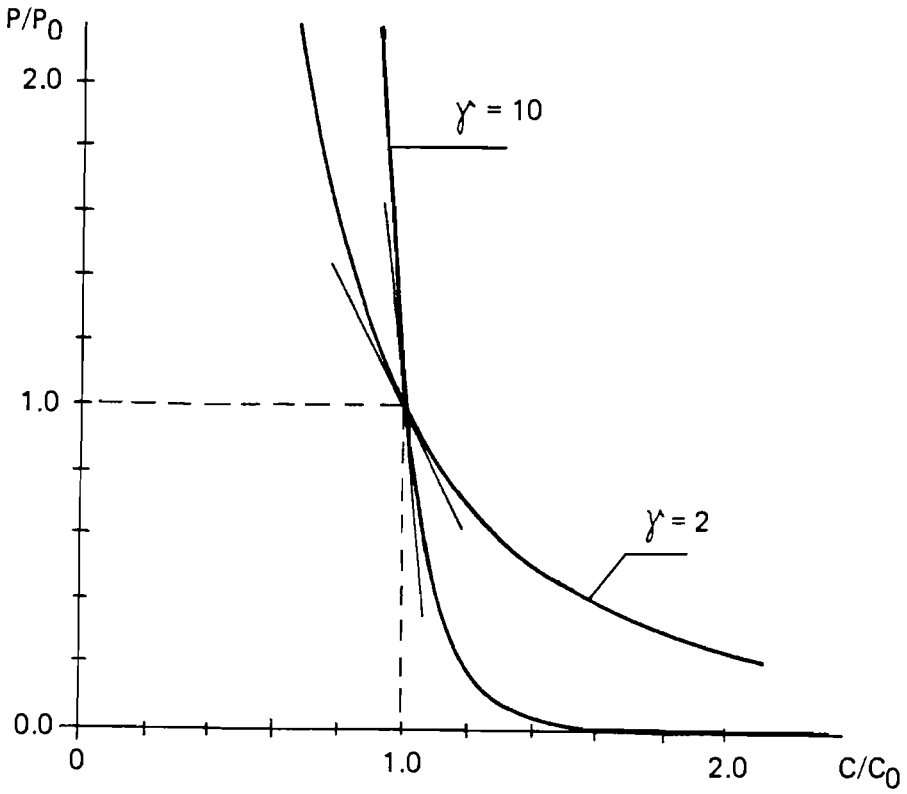


Figure 2. Consumption functions for price elasticities $(-1/\gamma)$ of $-.1$ and $-.5$.

4.2 Roundwood Production

The reference values in 1980 for log and pulpwood production as well as industrial consumption are given in Table 6. The difference between production and consumption is attributed to net exports (or imports). The price statistics adopted in Table 3 refer to coniferous sawnwood only. However, we have adjusted the quantities of logs in Table 6 to include nonconiferous as well as coniferous logs. The same applies to quantities of pulpwood.

Pulpwood *production* in Table 6 includes roundwood production only. However, *consumption* includes both round pulpwood and residuals from mechanical wood processing. The total quantity of such residuals consumed in 1980 is given by (430.9 – 341.3) mill. m^3 = 89.6 mill. m^3; i.e., 11 percent of log consumption worldwide.

We assume for modeling purposes that roundwood production results from harvesting two size classes of trees. Large trees yield on the average a share of φ_i of logs per m^3 of roundwood produced in region i. The share of pulpwood is $(1 - \varphi_i)$. For the other size class, small trees, the share of logs is zero; i.e., harvesting of small trees yields only pulpwood. Let η_i be the average share in region i of harvested roundwood which enters the forest industries as raw material. The share $(1 - \eta_i)$ accounts for losses, fuelwood, and other nonindustrial uses of roundwood. Our tentative values for η_i (UNIDO 1983) and φ_i are presented in Table 7.

Table 6. Annual production and consumption of sawlogs and pulpwood (mill. m^3) in 1980, based on FAO (1982a).

	Sawlogs		Pulpwood	
Region	Production	Consumption	Production	Consumption
Northern Europe	50.9	51.1	48.3	62.4
Western Europe	61.8	70.8	35.7	49.8
USA	185.2	171.1	109.4	164.0
Canada	115.6	116.5	38.9	72.9
Japan	21.0	57.6	9.6	31.3
Rest of the World	406.9	374.3	99.4	50.5
Total	841.4	841.4	341.3	430.9

Table 7. Fraction of industrial roundwood recovered (η_i) from trees harvested and fraction of roundwood recovered as logs (φ_i) from large trees harvested in region i.

i	η_i	φ_i
Northern Europe	.835	.85
Western Europe	.825	.85
USA	.861	.85
Canada	.861	.85
Japan	.869	.85
Rest of the World	.531	.85

The reference value for harvesting large trees is determined by production in Table 6 divided by the factor $\varphi_i \eta_i$. Similarly, the reference value for harvesting small trees is obtained by subtracting first from the pulpwood production (in Table 6) the production resulting from large tree harvesting (i.e., subtracting $(1 - \varphi_i)\eta_i$ times large tree harvesting), and dividing the reminder by η_i. The resulting resulting reference quantities for 1980 are shown in Table 8.

The mill prices for logs and pulpwood, denoted by π_{i1}^0 and π_{i2}^0, respectively, were assumed (based partly on FAO statistics, partly on subjective estimates) to be as shown in Table 9 for 1980.

Table 8. Estimated volume (mill. m^3) of timber harvested in 1980.

Region	Large trees	Small trees	Total
Northern Europe	71.7	47.1	118.8
Western Europe	88.1	30.0	118.1
USA	253.0	89.0	342.0
Canada	158.0	21.5	179.5
Japan	28.4	6.7	35.1
Rest of the World	901.5	51.9	953.4
Total	1500.7	246.2	1746.9

Table 9. Reference prices in 1980 for logs and pulpwood ($/$m^3$), and supply parameters α and β.

	Price		Parameter α		Parameter β	
Region	Logs	Pulpwood	Large trees	Small trees	Large trees	Small trees
Northern Europe	55	45	.14	6.64	1.35	0.45
Western Europe	70	50	2.40	20.87	0.70	0.20
USA	40	20	.04	2.86	1.20	0.40
Canada	30	24	15.07	15.23	0.10	0.10
Japan	100	58	15.27	41.67	0.50	0.10
Rest of the World	40	20	2.50	2.18	0.30	0.40

In order to determine the parameters α and β for the marginal cost curve $Q = \alpha y^{\beta}$ (by tree size and by region), we calculate first the prices π_{i1}^{*} and π_{i2}^{*} for large and small trees, respectively, as follows:

$$\pi_{i1}^{*} = \eta_i \left[\varphi_i \pi_{i1}^{0} + (1-\varphi_i)\pi_{i2}^{0}\right] \tag{22}$$

$$\pi_{i2}^{*} = \eta_i \pi_{i2}^{0} \tag{23}$$

We shall require that these prices result from the regional cost functions at the reference harvest volumes, y^{*}, as given in Table 8. In addition, we shall require that the average stumpage price, calculated as the average difference between wood price π^{*} and marginal cost, corresponds to the estimated stumpage price in 1980. The marginal cost associated with the reference harvest volume y^{*} is $\pi^{*} = \alpha(y^{*})^{\beta}$. Since the marginal cost associated with an arbitrary harvest volume y is $\pi = \alpha y^{\beta}$, this can also be written as $\pi = \pi^{*}(y/y^{*})^{\beta}$. Then the average difference between wood price and marginal cost (i.e., the stumpage price, s^{*}) is given by

$$s^{*} = (\pi^{*}/y^{*}) \int_0^{y^{*}} \left[1-(y/y^{*})^{\beta}\right] dy = \frac{\beta}{\beta+1}\pi^{*}$$

i.e.,

$$\beta = \frac{s^{*}}{\pi^{*}-s^{*}}. \tag{24}$$

Given our estimates for s^{*} and y^{*}, the resulting parameter values α and β are given in Table 9. Figure 3 shows typical shapes of the wood supply curves.

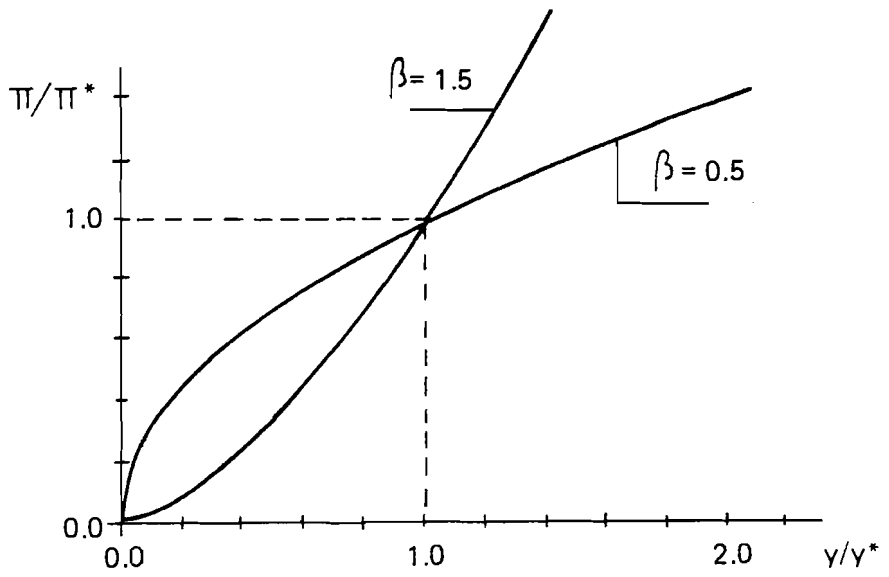


Figure 3. Wood supply functions $\pi/\pi^{*} = (y/y^{*})^{\beta}$ for β=.5 and β=1.5.

4.3 Industrial Processing

FAO statistics for industrial production in 1980 (FAO 1982a) yield the reference values summarized in Table 10. Pulp includes bleached sulphite and bleached sulphate pulps, and packaging paper includes paper board.

For sawnwood and panels two technologies are considered for each, one referring to estimated capacity in 1980, denoted by T_1, and another to new capacity, denoted by T_3, resulting from investments. The latter is endogenous in our model. For all other products, production technologies are handled similarly except that the 1980 capacity is split into two efficiency categories. We denote the current modern capacity by T_1, and the current inefficient capacity by T_2. Again, technology T_3 refers to new investments.

Within each region, consumption of wood for sawnwood and panel production was assumed to be independent of technology; thus, the only difference between T_1 and T_3 for mechanical wood products is in the processing cost. Log and pulpwood input in m^3 per m^3 of output is given in Table 11. Negative coefficients refer to net output of pulpwood residuals.

For pulp and paper, pulpwood consumption per ton accounting for fiber inputs other than bleached pulp is given in Table 12. The bleached pulp consumption per ton of paper is given in Table 13 and the input of recycled paper in Table 14. In each case, the input coefficients for technologies T_1 and T_3 are assumed equal; i.e., raw material use by plants representing new investments corresponds to raw material use by current modern technology.

Table 10. Annual production (mill. m^3, mill. ton) in 1980 (FAO 1982a).

Region	Sawn-wood	Panels	Pulp	News-print	Printing paper	Packaging paper
Northern Europe	23.9	4.6	6.8	3.7	3.5	5.4
Western Europe	39.6	20.9	3.5	2.3	10.4	11.6
USA	75.3	26.2	18.6	4.1	13.7	35.4
Canada	41.9	4.8	8.3	8.6	1.5	2.7
Japan	37.1	10.3	4.3	2.7	4.1	9.5
Rest of the World	210.6	34.4	8.3	5.0	9.2	10.9
Total	428.4	101.2	49.8	26.4	42.4	75.5

Table 11. Log and pulpwood consumption (production) per m^3 of sawnwood and panels (m^3/m^3).

	Sawnwood		Panels	
Region	Logs	Pulpwood	Logs	Pulpwood
Northern Europe	2.06	−0.37	0.46	0.54
Western Europe	1.69	−0.26	0.18	0.82
USA	1.78	−0.67	1.32	−0.32
Canada	2.60	−0.80	1.59	−0.59
Japan	1.20	−0.20	1.28	−0.28
Rest of the World	1.60	0.00	1.08	−0.08

Table 12. Pulpwood input coefficients (m^3/ton).

	Pulp		Newsprint		Printing paper		Packaging paper	
Region	T_1, T_3	T_2	T_1, T_3	T_2	T_1, T_3	T_2	T_1, T_3	T_2
Northern Europe	4.9	5.4	2.1	2.0	1.10	0.70	2.90	2.80
Western Europe	4.5	4.8	1.6	1.4	0.51	0.58	0.65	0.65
USA	4.2	4.5	1.55	2.0	0.35	0.25	2.04	2.15
Canada	5.5	5.9	2.2	2.2	0.75	0.55	2.55	2.00
Japan	4.0	4.7	1.5	1.5	0.50	0.0	1.60	1.10
Rest of the World	4.7	5.2	2.2	2.2	0.50	0.15	1.35	1.35

Table 13. Bleached pulp input coefficients (ton/ton).

	Newsprint		Printing paper		Packaging paper	
Region	T_1, T_3	T_2	T_1, T_3	T_2	T_1, T_3	T_2
Northern Europe	.15	.20	.39	.52	.23	.20
Western Europe	.15	.23	.56	.56	.20	.20
USA	.21	.20	.64	.66	.19	.12
Canada	.19	.20	.66	.61	.31	.24
Japan	.20	.19	.70	.80	.17	.14
Rest of the World	.19	.21	.62	.70	.10	.10

Table 14. Input coefficients of recycled paper (ton/ton).

	Newsprint		Printing paper		Packaging paper	
Region	T_1, T_3	T_2	T_1, T_3	T_2	T_1, T_3	T_2
Northern Europe	.04	.04	.0	.0	.10	.15
Western Europe	.21	.27	.05	.04	.68	.68
USA	.19	.04	.10	.11	.30	.36
Canada	.0	.0	.0	.0	.29	.53
Japan	.21	.24	.10	.12	.54	.70
Rest of the World	.0	.0	.07	.10	.45	.45

Production costs as summarized in Table 15 (other than wood cost) are assumed to be proportional to the quantity produced. For existing capacity (technologies T_1 and T_2) we shall account for variable production costs only (such as other material inputs, energy, and nonfixed labor costs). For new capacity (technology T_3), all costs, such as capital costs, are included.

Production capacities are given in Table 16 by region, product and technology. For new investments an upper bound is set roughly to 20% of existing capacity. Waste paper recycling rates (based on ECE 1976) were applied to 1980 paper consumption to calculate availability of recycled paper.

Table 15. Production costs ($/m^3, $/ton) in 1980. Wood and fiber costs are excluded and only variable costs are included for technologies T_1 and T_2.

		Northern Europe	Western Europe	USA	Canada	Japan	Rest of the World
Sawnwood	T_1	65	70	60	45	60	60
	T_3	130	140	120	90	120	120
Panels	T_1	250	250	250	250	250	250
	T_3	320	320	320	320	320	320
Pulp	T_1	147	175	185	166	175	180
	T_2	256	290	270	267	280	280
	T_3	260	300	275	268	290	290
Newsprint	T_1	270	266	204	172	237	240
	T_2	335	350	254	201	294	290
	T_3	351	354	280	245	314	315
Printing paper	T_1	326	395	286	222	330	330
	T_2	405	475	330	281	410	420
	T_3	410	483	348	284	415	425
Packaging paper	T_1	262	318	205	213	298	300
	T_2	335	376	250	245	331	330
	T_3	342	386	268	273	343	345
Recycled paper		155	135	80	110	145	140

Table 16. Production capacities (m^3/year, mill. ton/year), and recycled paper availability (mill. ton/year) in 1980.

		Northern Europe	Western Europe	USA	Canada	Japan	Rest of the World
Sawnwood	T_1	23.9	39.6	75.3	41.9	37.1	210.6
	T_3	4.7	5.7	11.7	8.1	6.1	28.1
Panels	T_1	4.6	21.3	27.7	4.8	10.3	34.4
	T_3	0.9	4.3	5.5	1.0	2.0	6.7
Pulp	T_1	5.5	1.0	12.3	5.9	3.0	3.3
	T_2	1.5	2.5	6.3	2.4	1.3	4.7
	T_3	1.4	0.7	3.5	4.0	0.8	1.6
Newsprint	T_1	2.9	1.1	3.3	4.9	1.5	2.3
	T_2	0.8	1.2	0.8	3.9	1.2	2.7
	T_3	0.7	0.4	0.8	1.8	0.5	0.9
Printing paper	T_1	2.2	4.2	6.6	0.7	1.7	2.5
	T_2	1.4	6.5	7.6	0.9	2.6	6.7
	T_3	0.7	2.1	2.8	0.3	0.9	1.6
Packaging paper	T_1	2.9	6.6	27.6	1.9	3.4	5.2
	T_2	3.5	10.8	11.3	1.4	7.3	29.7
	T_3	1.3	3.5	7.8	0.7	2.1	7.0
Recycled paper		1.0	12.8	14.4	1.3	8.0	16.5

4.4 Transportation Costs

Estimated transportation costs for logs, sawnwood, pulp, and different paper grades are given in Table 17. For pulpwood the transportation cost is assumed to be equal to that of logs. Similarly, transportation costs for sawnwood and panels were assumed to be approximately equal. The cost of transporting recycled paper is assumed to be 80% of that of transporting pulp. In general, these estimates must be considered highly preliminary. Transportation costs, particularly with respect to such charges as port handling fees, are extremely variable and location-specific. Our estimates are based on data reported for the USA by Hassan and Wisdom (1982) and Sedjo (1983), with subjective adjustments for other regions of origin.

Table 17. Transportation costs ($/m^3, $/ton) between regions. (Regions: 1 = Northern Europe, 2 = Western Europe, 3 = USA, 4 = Canada, 5 = Japan, 6 = Rest of the World).

Logs and Pulpwood

Exporting region	Importing region 1	2	3	4	5	6
1	-	12	23	22	52	27
2	12	-	22	20	50	27
3	23	22	-	11	24	27
4	22	20	15	-	23	27
5	52	50	24	23	-	27
6	14	22	25	29	18	-

Sawnwood and Panels

Exporting region	Importing region 1	2	3	4	5	6
1	-	13	24	23	53	28
2	13	-	23	21	51	28
3	24	23	-	12	25	28
4	23	21	14	-	24	28
5	53	51	25	24	-	28
6	28	28	28	28	28	-

Pulp

Exporting region	Importing region 1	2	3	4	5	6
1	-	39	97	89	242	116
2	39	-	89	81	234	116
3	97	89	-	36	99	116
4	89	81	47	-	98	116
5	242	235	101	98	-	116
6	116	116	116	116	116	-

Newsprint

Exporting region	Importing region 1	2	3	4	5	6
1	-	48	126	115	323	152
2	48	-	115	104	312	152
3	126	115	-	43	129	152
4	115	104	58	-	127	152
5	323	312	132	127	-	152
6	152	152	152	152	152	-

Printing paper

Exporting region	Importing region 1	2	3	4	5	6
1	-	54	138	127	353	167
2	54	-	126	115	341	167
3	138	126	-	49	142	167
4	127	115	65	-	140	167
5	353	341	145	140	-	167
6	167	167	167	167	167	-

Packaging paper

Exporting region	Importing region 1	2	3	4	5	6
1	-	46	114	105	286	137
2	46	-	104	95	277	137
3	114	104	-	42	117	137
4	105	95	55	-	116	137
5	286	277	119	116	-	137
6	137	137	137	137	137	-

5. OUTLINE OF DEMONSTRATION RUNS

To test the preliminary model's ability to represent the economic structure of the global forest sector and to provide a demonstration of its capabilities with respect to sensitivity analysis, we made a series of runs under a variety of scenario assumption. Figure 4 outlines the structure of these demonstration runs.

Two sets of runs were made, with one set representing the situation in 1980 and the other set simulating the situation around the year 2000. Detailed explanations of the assmptions used in formulating these scenarios are given in Section 6 (1980) and Section 7 (2000).

Scenario 1 is considered the Base Scenario for 1980 and was made to test the overall validity of the model as compared to the reference data for that year (Tables 4-6 and 8-10). Scenarios 2 and 3 test the sensitivity of the model to variations in price elasticities. Scenario 4 considers the effect on the global forest sector of a major increase in the value of the dollar as measured against other currencies.

Scenario 5 is the Base Scenario for 2000, based loosely on projections from United Nations agencies (ECE 1976 and 1981, FAO 1982b) plus information from Project collaborators. Scenario 6 considers the possible effects of a very large shift in demand between 1980 and 2000, while Scenario 7 simulates the forest sector in 2000 under a no-growth assumption with respect to demand. Scenario 8 tests the outcome of the imposition of import tariffs on forest products by two regions. Finally, Scenario 9 is intended to test the effects on the global forest economy of a large increase in timber supply in the United States.

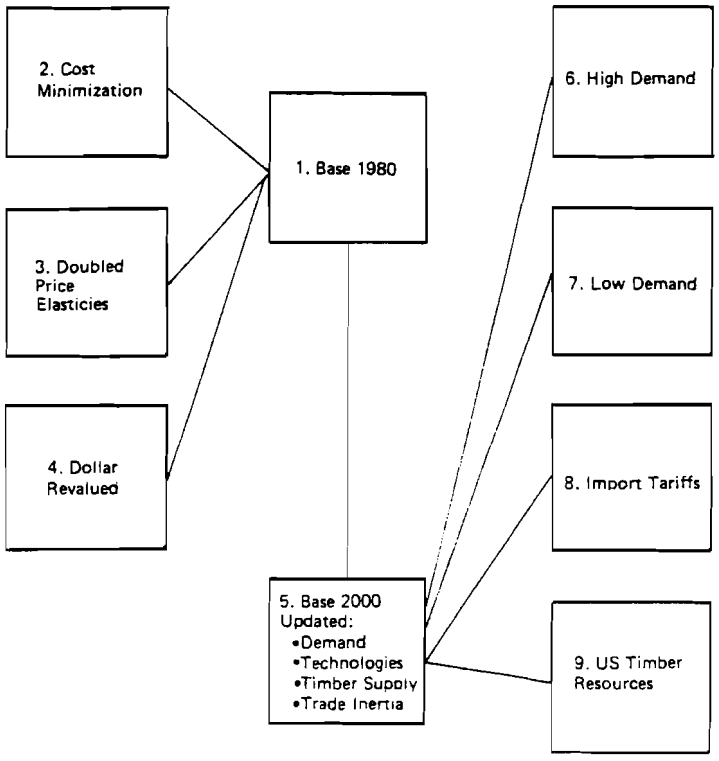


Figure 4. Outline of the nine scenarios considered in the demonstration runs made with the preliminary version of the GTM.

6. SCENARIOS FOR 1980

6.1 Scenario 1: Base Scenario 1980

For the Base Scenario we adopted the data described in Section 4. Investments were restricted to a maximum of approximately 20% of existing capacity. Upper bounds on trade flows were set at the level of one to two times the flow in 1980 according to FAO statistics. If the flow was nonexistent or small in 1980, upper bound was set to 1 million m^3 or 1 million tons. Lower bounds were set to approximately 80% of the actual 1980 trade flow.

The resulting consumption for sawnwood, panels and the various paper grades is reported together with the reference values of Table 4 in Table 18. The extremely good fit is partially explained by the relatively low price elasticities, a characteristic for this group of forest products. The prices resulting from the Base Scenario and their reference values of Table 3 are given in Table 19. Two-thirds of the prices computed by the model are within 5% of the reference values. Some of the larger differences (e.g., printing paper for Western Europe and for Japan) can be explained by average quality differences which influence reference prices. Such quality differences will be taken into account in the full-scale model given that average quality differences between regions can be measured in terms of $\$/m^3$ ($/ton).

Table 18. Consumption in the Base Scenario 1980 (above) and their reference values in 1980 (below) (mill. m^3/year, mill. ton/year).

Region	Sawn-wood	Panels	News-print	Printing paper	Packaging paper
Northern Europe	11.4	3.5	0.7	1.2	2.3
	11.4	3.5	0.7	1.2	2.3
Western Europe	62.8	23.9	5.1	11.4	14.6
	62.6	24.0	5.0	11.3	14.6
USA	86.3	26.4	10.9	14.6	32.6
	92.4	27.4	10.6	14.2	32.3
Canada	13.4	3.9	0.9	1.0	2.0
	14.1	4.2	0.9	1.0	2.0
Japan	45.5	10.6	2.7	4.0	9.6
	42.6	10.4	2.7	3.9	9.6
Rest of the World	214.1	31.5	6.8	10.4	12.0
	205.6	31.3	6.8	10.4	12.0
Total	433.5	99.8	27.1	42.6	73.1
	428.7	100.8	26.7	42.0	72.8

Table 19. Prices ($/m^3$, $/ton) in the Base Scenario 1980 (above) and reference values of Table 3 in 1980 (below).

Region	Sawn-goods	Panels	News-print	Printing paper	Packaging paper
Northern Europe	235	298	485	707	560
	230	320	470	720	550
Western Europe	248	344	533	761	586
	250	345	560	845	580
USA	159	309	428	607	421
	160	280	430	625	450
Canada	152	322	370	646	463
	145	275	400	640	450
Japan	203	352	493	749	538
	230	375	510	800	520
Rest of the World	187	293	438	713	460
	200	315	425	700	450

Production, consumption and net trade values as well as their reference values in 1980 are given in Table 20 for intermediate products (roundwood, pulp, and recyled paper). Trade in recycled paper is negligible in the Base Scenario, and therefore not reported.

The prices for logs, pulpwood, pulp and recycled paper are given in Table 21. We note that the reference price for pulp does not enter the model at all (since pulp is not a final product but is consumed within the forest industry). This may explain partially some major differences in pulp price as compared to the reference values. The prices for recycled paper are intended to cover all collection and processing costs. Therefore, they may appear high compared with existing data on recycled paper prices.

Forest industrial production is given in Table 22 by region, product, and technology. Recall that technology T_1 refers to existing modern technology, T_2 to existing inefficient technology, and T_3 to capacity resulting from new investments (which are endogeneous in the model).

Marginal values for capacity are reported in Table 23. For existing capacity m in region i a positive number indicates that capacity is fully employed. In this case the marginal value is the increment in profit that could be achieved in region i if an extra unit of similar capacity m were made available. For example, for pulp production (T_1) in the USA the marginal value is \$91/(ton/year). In order for an investment in such capacity to be profitable, the extra annual cost (e.g., capital cost) resulting from new investment should not exceed this value.

Table 20. Base Scenario 1980 results (above) for timber harvesting; roundwood and pulp production, net import, and consumption; and recycled paper consumption. Reference values for 1980 (below) based on FAO (1982a) and UNIDO (1983) are given below entries. Reference values for roundwood production and consumption, and for pulp production are the same as these reported in Section 4.

Region	Trees harvested (mill. m^3)		Logs (mill. m^3)			Pulpwood (mill. m^3)			Pulp (mill. ton)			Recycled Paper (mill. ton)
	Large	Small	Production	Import	Consumption	Production	Import	Consumption†	Production	Import	Consumption	
Northern Europe	73.6 71.7	35.5 47.1	52.3 50.9	1.1 0.2	53.4 51.1	38.9 48.3	5.8 5.2	53.9 62.4	6.5 6.8	−3.5 −3.5	3.0 3.3	.5
Western Europe	89.5 88.1	14.0 30.0	62.7 61.8	8.2 9.0	70.9 70.8	22.6 35.7	3.5 3.6	36.4 49.8	1.0 3.5	6.0 6.7	7.0 10.1	8.6
USA	252.7 253.0	108.1 89.0	184.9 185.2	−14.2 −14.1	170.7 171.1	125.7 109.4	−4.3 −4.8	180.8 164.0	20.7 18.6	−3.0 0.5	17.7 19.1	14.4
Canada	166.0 158.0	8.8 21.5	121.5 115.6	−2.6 0.9	118.9 116.5	29.0 38.9	−2.2 −2.3	63.9 72.9	5.9 8.3	−1.8 −5.5	4.1 2.0	1.3
Japan	22.3 28.4	0.5 6.7	16.5 21.0	38.3 36.6	54.8 57.6	3.4 9.6	15.7 13.6	28.8 31.3	3.0 4.3	1.2 1.3	4.2 5.7	6.6
Rest of the World	908.6 901.5	65.5 51.9	409.8 406.9	−30.8 −32.6	379.0 374.3	107.4 99.4	−18.5 −15.3	55.4 50.5	6.5 4.4	1.1 0.6	7.6 5.0	4.0
Total	1512.7 1500.7	232.4 246.2	847.7 841.4	0.0 0.0	847.7 841.4	327.0 341.3	0.0 0.0	419.2 430.9	43.6 45.9	0.0 0.1	43.6 46.0	

† Pulpwood consumption is not equal to production plus net import because production is limited to roundwood; consumption and trade include residues produced during sawnwood and panel production.

Table 21. Base Scenario prices (above) and their reference values in 1980 (below) based on FAO (1982a and 1982c) for intermediate products ($/m^3, $/ton). The reference prices of logs and pulpwood are also given in Table 9 above.

Region	Logs	Pulpwood	Pulp	Recycled paper
Northern Europe	58	39	454	155
	55	45	480	
Western Europe	72	43	456	135
	70	50	520	
USA	40	22	367	190
	40	20	465	
Canada	30	22	389	152
	30	24	465	
Japan	70	45	403	145
	100	58	530	
Rest of the World	42	22	394	140
	40	20	470	

If capacity is partially employed, then the marginal value is equal to zero. For example, panel production (T_1) in Japan is 8.0 mill. m^3 whereas capacity is 10.3 mill. m^3/year. A negative value refers to unemployed capacity. The marginal value then indicates the amount by which production would have to be subsidized in order to make it profitable. For example, for the inefficient capacity (T_2) of pulp mills in Western Europe, the marginal value is −40$/(ton/year). A subsidy of $40/ton would thus be required to make this capacity competitive.

For new capacity (T_3), zero marginal value means that investment is marginally profitable, and a negative number indicates the amount by which production costs, including capital recovery costs on the new investment, would have to be reduced in order to make the investment profitable. A positive number corresponds to the increment in profits that could be achieved (per unit increase in capacity) if our upper limit on new investments (20% of existing capacity) were relaxed. For instance, investment in Canada in printing paper production would yield annually $89 per ton above all production costs, including fixed costs and capital recovery on the investment costs.

The trade flow results for the Base Scenario are summarized in Tables 24 (a)-(i). Bilateral flows in physical units are given as well as marginal costs on trade flow restrictions. A negative marginal value means that the trade flow is at its lower bound. A positive marginal value means that the upper bound on the trade flow is binding. If a flow is strictly between its bounds, the marginal value is zero.

Table 22. Base Scenario 1980 final-product production (mill. m^3, mill. ton), with reference values of Table 10 for 1980 based on FAO (1982a).

		North. Europe	West. Europe	USA	Canada	Japan	Rest of World	Totals
Sawn-wood	T_1	23.9	39.6	75.3	41.9	37.1	210.6	
	T_3	1.0	.0	.0	.9	.0	3.1	
	Total	24.9	39.6	75.3	42.8	37.1	213.7	433.4
	Ref.	23.9	39.6	75.3	41.9	37.1	210.6	428.4
Panels	T_1	4.4	21.3	27.7	4.8	8.0	33.8	
	T_3	.0	.0	.0	.0	.0	.0	
	Total	4.4	21.3	27.7	4.8	8.0	33.8	100.0
	Ref.	4.6	20.9	26.2	4.8	10.3	34.4	101.2
Pulp	T_1	5.5	1.0	12.3	5.9	3.0	3.3	
	T_2	.0	.0	4.9	.0	.0	1.6	
	T_3	1.0	.0	3.5	.0	.0	1.6	
	Total	6.5	1.0	20.7	5.9	3.0	6.5	43.6
	Ref.	6.8	3.5	18.6	8.3	4.3	8.3	49.8
News-print	T_1	2.9	1.1	3.3	4.9	1.5	2.3	
	T_2	.0	.0	.8	3.9	1.2	2.7	
	T_3	.0	.4	.1	1.8	.0	.2	
	Total	2.9	1.5	4.2	10.6	2.7	5.2	27.1
	Ref.	3.7	2.3	4.1	8.6	2.7	5.0	26.4
Print-ing paper	T_1	2.2	4.2	6.6	.7	1.7	2.5	
	T_2	1.4	3.9	7.6	.9	.7	4.7	
	T_3	.7	.0	1.9	.3	.9	1.6	
	Total	4.3	8.1	16.1	1.9	3.2	8.8	42.4
	Ref.	3.5	10.4	13.7	1.5	4.1	9.2	42.4
Pack-aging paper	T_1	2.9	6.6	27.6	1.9	3.4	5.2	
	T_2	.3	5.1	11.3	1.2	5.4	2.1	
	T_3	.0	.0	.0	.0	.0	.0	
	Total	3.2	11.7	38.9	3.1	8.8	7.3	73.0
	Ref.	5.4	11.6	35.4	2.7	9.5	10.9	75.5

Table 23. Marginal values for capacity in the Base Scenario 1980 ($/($m^3$/year), $/(ton/year)).

		Northern Europe	Western Europe	USA	Canada	Japan	Rest of the World
Saw-mills	T_1	65	67	43	45	44	60
	T_3	0	−3	−17	0	−16	0
Panel production	T_1	0	46	14	37	0	0
	T_3	−70	−24	−70	−33	−70	−70
Pulp mills	T_1	113	88	91	102	48	111
	T_2	−16	−40	0	−8	−89	0
	T_3	0	−37	2	0	−67	1
New print production	T_1	57	101	76	77	77	75
	T_2	−27	−19	51	45	20	17
	T_3	−24	13	0	5	0	0
Printing paper production	T_1	160	82	62	151	100	118
	T_2	38	0	11	114	0	0
	T_3	76	−6	0	89	15	23
Packaging paper production	T_1	63	58	48	37	22	30
	T_2	0	0	14	0	0	0
	T_3	−17	−10	−15	−23	−23	−15

Table 24. Annual bilateral trade flows (mill. m^3, mill. ton) and marginal costs for trade inertia constraints ($/$m^3$, $/ton) in the Base Scenario. Total exports and imports are given in comparison with the FAO values for 1980. (Regions: 1 = Northern Europe, 2 = Western Europe, 3 = USA, 4 = Canada, 5 = Japan, 6 = Rest of the World).

(a) Logs

Trade Flows

	1	2	3	4	5	6	Total exports	FAO
1		1.0				.3	1.3	1.2
2							.0	1.7
3		1.0		1.0	11.5	1.1	14.6	14.7
4	1.0	1.0	.3		1.2		3.5	1.1
5							.0	.0
6	1.4	5.2			25.6		32.2	36.2
Total imports	2.4	8.2	.3	1.0	38.3	1.4	51.6	54.9
FAO	1.4	10.7	.6	2.0	36.6	3.6	54.9	

Marginal costs

	1	2	3	4	5	6
1		2	-42	-50	-21	-44
2	-26		-55	-62	-33	-58
3	-4	11		-20	26	-25
4	6	22	-6		36	-16
5	-83	-67	-74	-82		-75
6	3	9	-27	-40	30	

(b) Pulpwood

Trade Flows

	1	2	3	4	5	6	Total exports	FAO
1						.1	.1	2.9
2	.2					.1	.3	6.5
3	.4			.3	4.8		5.5	6.9
4	.1	.6	1.2		.4	.2	2.5	3.0
5							.0	.0
6	5.2	3.2			10.5		18.9	20.1
Total imports	5.9	3.8	1.2	.3	15.7	.4	27.3	39.4
FAO	8.1	10.1	2.1	.7	13.6	4.8	39.4	

Marginal costs

	1	2	3	4	5	6
1	-9	-41	-40	-47	-45	
2	-15		-43	-41	-48	-48
3	-5	-1		-11	-1	-27
4	-4	1	-15		0	-27
5	-57	-52	-47	-46		-50
6	4	-1	-25	-29	5	

(c) Sawnwood

Trade Flows

	1	2	3	4	5	6	Total exports	FAO
1		13.1				2.7	15.8	13.3
2						.9	.9	6.2
3	1.0	.2		.1	3.0	2.4	6.7	4.6
4	1.0	2.8	17.7		5.2	2.8	29.5	29.0
5							.0	.0
6	.2	8.0			.2		8.4	12.9
Total imports	2.2	24.1	17.7	.1	8.4	8.8	61.3	66.0
FAO	1.8	23.4	22.2	.7	4.9	9.8	62.8	

Marginal costs

	1	2	3	4	5	6
1		0	-101	-107	-85	-76
2	-26		-112	-117	-96	-90
3	53	67		-19	19	0
4	61	76	-7		27	7
5	-21	-6	-69	-75		-44
6	21	34	-56	-63	-12	

(d) Panels

Trade Flows

	1	2	3	4	5	6	Total exports	FAO
1		.2			.5	.2	.9	1.9
2	.1					.2	.3	5.1
3		.6		.3	1.0	.3	2.2	1.0
4		.4			1.0		1.4	.8
5			.1				.1	.1
6	.1	1.6	.9	.3	.2		3.0	6.9
Total imports	.2	2.8	1.0	.6	2.7	.7	8.0	15.8
FAO	.7	8.2	2.1	.2	.3	3.8	15.3	

Marginal costs

	1	2	3	4	5	6
1		32	-14	0	0	-34
2	-60		-59	-44	-44	-80
3	-36	11		0	17	-45
4	-48	0	-28		5	-58
5	-108	-60	-69	-55		-88
6	-24	22	-13	0	30	

(e) Pulp

Trade Flows

	1	2	3	4	5	6	Total exports	FAO
1		2.4			.1	1.1	3.6	3.7
2						.2	.2	1.1
3		2.5			.6	1.0	4.1	2.6
4		.7	.9		.2	.1	1.9	6.4
5							.0	.1
6	.1	.6	.2		.4		1.3	1.3
Total imports	.1	6.2	1.1	.0	1.3	2.4	11.1	15.2
FAO	.2	7.8	3.1	.9	1.4	1.9	15.3	

Marginal costs

	1	2	3	4	5	6
1		-37	-184	-154	-294	-176
2	-41		-178	-148	-288	-179
3	-10	0		-14	-64	-90
4	-24	-14	-69		-84	-111
5	-190	-181	-136	-112		-125
6	-55	-53	-142	-121	-107	

(f) Newsprint

Trade Flows

	1	2	3	4	5	6	Total exports	FAO
1		2.0	.1			1.0	3.1	3.2
2							.0	.3
3						.2	.2	.2
4	1.0	1.2	6.7			.7	9.6	7.7
5							.0	.1
6		.3					.3	1.0
Total imports	1.0	3.5	6.8	.0	.0	1.9	13.2	12.5
FAO	.2	3.1	6.6	.0	.1	2.8	12.8	

Marginal costs

	1	2	3	4	5	6
1		0	-183	-230	-315	-197
2	-96		-220	-267	-352	-247
3	-69	-10		-101	-64	-142
4	0	59	0		-4	-84
5	-330	-272	-197	-250		-207
6		-105	-57	-162	-220	-97

(g) Printing paper

Trade Flows

	1	2	3	4	5	6	Total exports	FAO
1		2.8	.1			.3	3.2	2.5
2	.1					1.0	1.1	2.9
3		1.0		.1	.9	.1	2.1	.2
4		.5	.4			.1	1.0	.7
5						.2	.2	.2
6							.0	.5
Total imports	.1	4.3	.5	.1	.9	1.7	7.6	7.0
FAO	.2	3.7	.7	.1	.0	1.7	6.7	

Marginal costs

	1	2	3	4	5	6
1		0	-238	-188	-311	-161
2	-108		-280	-230	-353	-215
3	-38	28		-10	0	-61
4	-66	0	-104		-37	100
5	-395	-329	-287	-243		-203
6	-173	-119	-273	-234	-131	

(h) Packaging paper

Trade Flows

	1	2	3	4	5	6	Total exports	FAO
1		.5			.1	1.5	2.1	3.5
2	.1					1.6	1.7	2.2
3	1.0	2.0		.9	.7	1.7	6.3	3.3
4		2.0					2.0	.8
5						.1	.1	.1
6	.1	.1					.2	1.0
Total imports	1.2	4.6	.0	.9	.8	4.9	12.4	10.9
FAO	.3	5.1	.2	.1	.3	2.2	8.2	

Marginal costs

	1	2	3	4	5	6
1		-20	253	-202	-308	-237
2	-72		-269	-218	-325	-263
3	25	61		0	0	-98
4	-8	28	-97		-41	-140
5	-264	-229	-236	-191		-215
6	-37	-11	-176	-134	-59	

(i) Recycled paper

Marginal costs

	1	2	3	4	5	6
1		-51	-43	-74	-204	-108
2	-11		-16	-42	-177	-88
3	-112	-128		-66	-124	-142
4	-68	-82	0		-109	-105
5	-184	-198	-36	-71		-98
6	-77	-98	-43	-81	-88	

6.2 Scenarios 2 and 3: Price Elasticity Variations

Two variations on price elasticity assumptions were tested. In Scenario 2, all elasticities for final products were set to zero. The model solution thus represents a situation in which demand (represented by 1980 apparent consumption as reported by FAO) is satisfied at minimum cost. In Scenario 3, these price elasticities for final products were *doubled* as compared with the Base Scenario (i.e., the elasticities used were twice those listed in Table 5).

The resulting prices, together with prices from the 1980 Base Scenario, are given in Table 25. The associated results for consumption are listed in Table 26. Log and pulpwood consumption and price results are summarized in Table 27.

The maximum deviations among these three scenarios occur in the sawnwood category. Sawnwood prices computed in Scenario 2 are about 10% lower than in Scenario 3 for the European Regions, 20% lower for Japan, and 48% lower for the rest of the world. The North American prices show no change for the two scenarios. In conjunction with these price changes, consumption tends to be slightly lower in Scenario 2 than in Scenario 3 for North America and slightly higher for the other regions. Changes in consumption are modest, however, since the demand curves are inelastic for all of the scenarios.

Changes in panel prices and consumption among the three scenarios are slightly greater than those for the three categories of paper products. With the exception of sawnwood, however, the scenario runs suggests that both prices and consumption are relatively independent of even fairly large changes in elasticity. Because the sawnwood industry is so fragmented, with a predominance of small, independent sawmills in many regions, we were not able to make reliable estimates of aggregate processing costs for sawnwood, and this very likely contributes to the variation observed in the prices of sawnwood between Scenarios 2 and 3.

Table 25. Forest product prices ($/m^3, $/ton) in Scenarios 2 and 3 compared with the Base Scenario 1980.

Region	Scenario	Sawn wood	Panels	News-print	Printing paper	Packaging paper
Northern Europe	Scenario 2	214	300	480	706	560
	Base 1980	235	298	485	707	560
	Scenario 3	236	298	491	707	560
Western Europe	Scenario 2	227	346	528	760	586
	Base 1980	248	344	533	761	586
	Scenario 3	249	335	539	761	586
USA	Scenario 2	166	322	423	605	413
	Base 1980	159	309	424	607	421
	Scenario 3	166	300	424	607	421
Canada	Scenario 2	152	324	365	645	455
	Base 1980	152	322	370	646	463
	Scenario 3	152	313	366	646	463
Japan	Scenario 2	176	354	467	747	534
	Base 1980	203	352	493	749	538
	Scenario 3	212	352	492	749	538
Rest of the World	Scenario 2	126	293	438	714	460
	Base 1980	187	293	438	713	460
	Scenario 3	187	393	438	713	460

Table 26. Consumption of forest products (mill. m^3/year, mill. ton/year) in Scenarios 2 and 3 compared with the Base Scenario 1980.

Region	Scenario	Sawn wood	Panels	News-print	Printing paper	Packaging paper
Northern Europe	Scenario 2	11.4	3.5	0.7	1.2	2.3
	Base 1980	11.3	3.6	0.7	1.2	2.3
	Scenario 3	11.4	3.5	0.7	1.2	2.3
Western Europe	Scenario 2	62.8	23.9	5.1	11.4	14.6
	Base 1980	62.9	24.4	5.1	11.5	14.6
	Scenario 3	62.6	24.0	5.0	11.3	14.6
USA	Scenario 2	86.3	26.4	10.9	14.6	32.6
	Base 1980	88.5	25.9	10.7	14.3	32.9
	Scenario 3	92.4	27.4	10.6	14.2	32.3
Canada	Scenario 2	13.4	3.9	0.9	1.0	2.0
	Base 1980	13.5	3.8	0.9	1.0	2.0
	Scenario 3	14.1	4.2	0.9	1.0	2.0
Japan	Scenario 2	45.5	10.6	2.7	4.0	9.6
	Base 1980	45.5	10.8	2.8	4.0	9.5
	Scenario 3	42.6	10.4	2.7	3.9	9.6
Rest of the World	Scenario 2	214.1	31.5	6.8	10.4	12.0
	Base 1980	214.3	31.7	6.7	10.4	12.0
	Scenario 3	205.6	31.3	6.8	10.4	12.0
Totals	Scenario 2	433.5	99.8	27.1	42.6	72.8
	Base 1980	436.0	100.2	26.9	42.4	73.3
	Scenario 3	428.7	100.8	26.7	42.0	72.8

Table 27. Consumption (mill. m^3/year) and prices ($/$m^3$) of logs and pulpwood in Scenarios 2 and 3 compared with the Base Scenario 1980.

		Consumption		Price	
Region	Scenario	Logs	Pulpwood	Logs	Pulpwood
Northern Europe	Scenario 2	51.3	53.4	55	40
	Base 1980	53.3	53.9	58	40
	Scenario 3	53.5	54.0	59	40
Western Europe	Scenario 2	70.9	36.3	72	43
	Base 1980	70.9	36.4	72	43
	Scenario 3	70.9	36.4	72	43
USA	Scenario 2	170.7	178.7	40	21
	Base 1980	170.7	180.8	40	22
	Scenario 3	170.7	180.2	40	22
Canada	Scenario 2	119.7	63.5	31	22
	Base 1980	118.9	63.9	30	22
	Scenario 3	121.2	64.1	31	22
Japan	Scenario 2	54.8	28.5	90	42
	Base 1980	54.8	28.8	90	45
	Scenario 3	54.8	29.0	90	45
Rest of the World	Scenario 2	373.3	55.5	41	22
	Base 1980	379.0	55.4	42	22
	Scenario 3	381.8	55.2	42	22
Totals	Scenario 2	840.7	415.9		
	Base 1980	847.6	419.2		
	Scenario 3	852.9	418.9		

6.3 Scenario 4: Exchange Rate Variations

One of the important considerations in any analysis of international trade is the possible effect of changing exchange rates. As a simple test of model sensitivity with respect to exchange rates, we increased our 1980 estimates of both timber harvesting and processing costs in the North American regions by one-third, reflecting the recent exchange rate development. Scenario 4 thus represents a situation in which the value of the US and Canadian dollars has increased substantially by comparison with all other currencies. The results of this analysis, with the corresponding figures for the 1980 Base Scenario shown for comparison, are given in Tables 28–31.

Prices computed by the model for Scenario 4 show major increases as compared to the Base Scenario for all products in the North American regions except sawnwood, with moderate increases in Europe and Japan and minor increases in the rest of the world. Consumption figures show a slight decrease overall, with the effect being most pronounced in the USA. Production in the USA and Canada decreases markedly by comparison with the Base Scenario. This is partially offset by moderate to large increases in the rest of the world. Prices of logs and pulpwood generally increase, with the change being most pronounced in North America, modest in Europe and Japan, and relatively minor in the rest of the world.

Perhaps the most significant effect of the change in the exchange rate is its influence on international trade. The trade flow matrices, which are not included here because of space considerations, indicate that a strengthened dollar would tend to have the effect of replacing exports of final products from North America with exports of raw materials. The North American regions would increase imports of final products, and other regions would tend to increase domestic production while substantially reducing imports of final products from the USA and Canada. The region gaining most from this situation would be the rest of the world, which would find significantly improved markets for its products, particularly in Western Europe, the USA, and Japan.

Table 28. Prices ($/m^3, $/ton) in Scenario 4 compared with the Base Scenario 1980.

Region	Scenario	Sawn-wood	Panels	News-print	Printing paper	Packaging paper
Northern Europe	Scenario 4	236	358	523	743	575
	Base 1980	235	298	454	707	560
Western Europe	Scenario 4	249	372	571	797	601
	Base 1980	248	344	533	761	586
USA	Scenario 4	159	391	525	771	483
	Base 1980	159	309	428	607	421
Canada	Scenario 4	159	382	467	706	518
	Base 1980	152	322	370	646	463
Japan	Scenario 4	203	378	510	820	557
	Base 1980	203	352	493	749	538
Rest of the World	Scenario 4	187	343	442	718	462
	Base 1980	187	293	438	713	460

Table 29. Consumption (mill. m^3/year, mill. ton/year) in Scenario 4 and comparison with the Base Scenario 1980.

Region	Scenario	Sawn wood	Panels	News-print	Printing paper	Packaging paper
Northern Europe	Scenario 4	11.3	3.4	0.7	1.2	2.3
	Base 1980	11.4	3.5	0.7	1.2	2.3
Western Europe	Scenario 4	62.7	23.4	5.0	11.4	14.5
	Base 1980	62.8	23.9	5.1	11.4	14.6
USA	Scenario 4	86.3	24.1	10.1	14.1	32.0
	Base 1980	86.3	26.4	10.9	14.6	32.6
Canada	Scenario 4	13.1	3.7	0.9	1.0	2.0
	Base 1980	13.4	3.9	0.9	1.0	2.0
Japan	Scenario 4	45.5	10.4	2.7	3.9	9.5
	Base 1980	45.5	10.6	2.7	4.0	9.6
Rest of the World	Scenario 4	214.1	31.0	6.7	10.4	12.0
	Base 1980	214.1	31.5	6.8	10.4	12.0
Total	Scenario 4	433.0	96.0	26.1	42.0	72.3
	Base 1980	433.5	99.8	27.1	42.6	73.1

Table 30. Production (mill. m^3/year, ton/year) in Scenario 4 and comparison with the Base Scenario 1980.

Region	Scenario	Sawn wood	Panels	Pulp	News-print	Printing paper	Packaging paper
Northern Europe	Scenario 4	24.9	4.6	6.9	3.7	4.3	4.2
	Base 1980	24.9	4.4	6.5	2.9	4.3	3.2
Western Europe	Scenario 4	39.6	22.0	2.9	1.6	9.6	13.5
	Base 1980	39.6	21.3	1.0	1.5	8.1	11.7
USA	Scenario 4	75.3	21.4	17.1	4.1	13.2	35.7
	Base 1980	75.3	27.7	20.7	4.2	16.1	38.9
Canada	Scenario 4	41.9	3.3	5.9	8.8	1.9	1.9
	Base 1980	42.8	4.8	5.9	10.6	1.9	3.1
Japan	Scenario 4	37.1	10.3	3.8	2.7	4.1	9.5
	Base 1980	37.1	8.0	3.0	2.7	3.2	8.8
Rest of the World	Scenario 4	214.4	34.4	6.6	5.1	8.8	7.4
	Base 1980	213.7	33.8	6.5	5.2	8.8	7.3
Total	Scenario 4	433.2	96.0	43.2	26.0	41.9	72.2
	Base 1980	433.4	100.0	43.6	27.1	42.4	73.0

Table 31. Consumption (mill. m^3/year) and prices ($/$m^3$) of logs and pulpwood in Scenario 4 and comparison with the Base Scenario 1980.

		Consumption		Price	
Region	Scenario	Logs	Pulpwood	Logs	Pulpwood
Northern Europe	Scenario 4	53.3	60.4	59	43
	Base 1980	53.3	53.9	58	40
Western Europe	Scenario 4	71.1	47.8	72	47
	Base 1980	70.9	36.4	72	43
USA	Scenario 4	162.3	156.7	50	26
	Base 1980	170.7	180.8	40	22
Canada	Scenario 4	114.1	57.3	41	27
	Base 1980	118.9	63.9	30	22
Japan	Scenario 4	57.7	32.5	97	50
	Base 1980	54.8	28.8	90	45
Rest of the World	Scenario 4	380.7	55.9	42	23
	Base 1980	379.0	55.4	42	22
Total	Scenario 4	839.2	410.6		
	Base 1980	847.6	419.2		

7. SCENARIOS FOR 2000

The preliminary version of the GTM is not explicitly implemented over time. That is, we are not yet able to make multi-period runs in which the results for one period are used automatically to drive the model for the subsequent period. However, in order to demonstrate the capabilities of the spatial equilibrium model for projecting possible structural changes in the forest sector of the global economy over time, we have used exogenous estimates of shifts in demand and other changes in order to make a series of scenario runs for 2000. This section describes the assumptions and results of these five scenario runs.

7.1 Scenario 5: Base Scenario 2000

In developing the Base Scenario we made an effort to model a situation that might be described as a "reasonably likely" outcome of current trends in the forest sector. In doing so, we assumed that currently inefficient capacity (technology T_2 in the 1980 scenarios) would be completely retired by the year 2000; thus, variables corresponding to this technology vanish. The category of currently modern capacity (technology T_1) was maintained at the level of capacity used for 1980, and the maximum capacity of new investments (technology T_3) was set at approximately 200% of the total capacity existing in 1980. All lower bounds on trade-flow variables were set equal to zero, and upper bounds were relaxed. Timber supply in Northern and Western Europe was held constant at the 1980 level, under the assumption that those regions have achieved their long-term sustained yield levels. Timber resources for the remaining regions were increased by 50% as compared to 1980, thus reflecting a growth in timber supply of abut 2% annually in those regions.

Projected shifts in demand curves between 1980 and 2000 were estimated as shown in Table 32. These estimates are based loosely on ECE (1976 and 1981) and FAO (1982b), and include information on expected demand shifts obtained from Project collaborators. Price elasticities were held constant at the level of the 1980 Base Scenario (Table 5). Capacity of recycled paper processing was estimated by multiplying the demand shifters for paper from Table 32 by the 1980 capacity.

Results for Base Scenario 2000 are summarized in Tables 33–37. Also shown for comparison are the results from Base Scenario 1980.

The model projects consumption to increase at rates closely approximating the percentage increases implied by the multipliers in Table 32, although in general the increases are slightly less than the demand shifts would suggest, due to increased production costs.

As compared to 1980, the Base Scenario 2000 produces a general increase in price levels, with a tendency toward uniformity of prices among all regions for a particular final product. This trend, although less pronounced, is also suggested by the results for logs and pulpwood. Changes in the prices of logs are mixed, with some regions showing decreases and others exhibiting increases. The drop in the Japanese log price is particularly large, indicating that the modest increases in demand for sawnwood and panels are offset by the increased timber

Table 32. Multipliers† used to shift demand curves from the levels used in the 1980 Base Scenario to those used in the 2000 Base Scenario.

Region	Sawn-wood	Panels	News-print	Printing paper	Packaging paper
Northern Europe	1.17	1.42	1.18	1.49	1.31
Western Europe	1.11	1.36	1.23	1.47	1.39
USA	1.13	1.35	1.02	1.55	1.25
Canada	1.15	1.45	1.15	1.74	1.35
Japan	1.14	1.33	1.45	1.82	1.67
Rest of the World	1.43	3.00	1.97	2.60	2.18

† $(\text{Consumption}_{1980})\ (\text{multiplier}) \simeq \text{Consumption}_{2000}$

supply. Pulpwood prices increase in all regions, with substantial rises in Western Europe, North America, and Japan. This is due to relatively large shifts in demand for paper products, particularly printing paper.

The apparent anomaly of a decrease in log price in Western Europe in spite of increased log consumption (and a constant domestic timber supply) is explained by the fact that domestic sawnwood production shows no change from 1980, while imports of logs from North America and the rest of the world (where log prices are low) increase significantly.

Table 36 indicates that major changes in new investments would be expected under the 2000 Base Scenario in the USA and the rest of the world, with especially strong increases in the latter region for all products. New investment in Northern Europe is minor except for printing paper production, and other regions show moderate increases in investment for most products.

Analysis of trade flow results indicates major increases in imports of logs into Western Europe and Japan from North America and the rest of the world. For pulpwood, imports into the European regions and Japan from the rest of the world would be supplanted by increased imports from North America and increased domestic production (e.g., from logs processed into sawnwood). Sawnwood exports from North America would increase substantially, whereas consumption of panels worldwide would shift almost entirely to domestic production.†

†The latter result suggests a difficulty with the present model, which does not consider quality differences. This is particularly important with respect to trade flows in panels, since the panels category is an aggregate of many widely diversified products. Efforts to explicitly recognize quality differences will thus receive major emphasis in the implementation of the full-scale version of the **GTM**.

Table 33. Consumption in Base Scenarios 2000 and 1980 (mill. m^3, mill. ton).

Region	Scenario	Sawn-wood	Panels	Pulp	News-print	Printing paper	Packaging paper
Northern Europe	Base 2000	14.0	4.8	4.0	0.8	1.8	3.0
	Base 1980	11.4	3.5	3.0	0.7	1.2	2.3
	% change	+22	+37	+33	+14	+50	+30
Western Europe	Base 2000	75.6	31.6	9.7	6.2	16.7	20.2
	Base 1980	62.8	23.9	7.1	5.1	11.4	14.6
	% change	+20	+32	+37	+22	+46	+38
USA	Base 2000	95.9	33.0	30.6	10.7	22.3	40.0
	Base 1980	86.3	26.4	17.7	10.9	14.6	32.6
	% change	+11	+25	+73	−2	+53	+23
Canada	Base 2000	14.9	5.5	4.9	1.0	1.7	2.6
	Base 1980	13.4	3.9	4.1	0.9	1.0	2.0
	% change	+11	+41	+20	+11	+70	+30
Japan	Base 2000	54.1	13.8	5.4	3.8	7.1	15.7
	Base 1980	45.5	10.4	4.2	2.7	4.0	9.6
	% change	+19	+33	+29	+41	+78	+64
Rest of the World	Base 2000	304.2	92.4	16.1	12.9	26.8	26.0
	Base 1980	214.1	31.5	7.6	6.8	10.4	12.0
	% change	+42	+193	+112	+90	+158	+117
Total	Base 2000	558.7	181.1	70.7	35.4	76.4	93.5
	Base 1980	392.5	99.6	43.7	27.1	42.6	73.1
	% change	+42	+82	+62	+31	+79	+28

The trade flow report for pulp indicates a shift from the USA to Canada as a supplier of pulp to Western Europe and Japan. Newsprint generally shows a tendency toward increased domestic production, with diminishing trade. Printing papers also show markedly increased domestic production in all regions except Western Europe, where the increase is moderate. The large shift in demand for this product category, however, is sufficient to induce increased exports as well from Northern Europe and North America. Packaging papers show an increase in exports from the USA, with a reduction in exports from Canada.

Table 34. Prices in Base Scenarios 2000 and 1980 ($/m^3, $/ton).

Region	Scenario	Sawn-wood	Panels	Pulp	News-print	Printing paper	Packaging paper
Northern Europe	Base 2000	186	370	474	439	643	593
	Base 1980	235	298	454	485	707	560
Western Europe	Base 2000	200	375	513	545	804	619
	Base 1980	248	344	456	533	761	586
USA	Base 2000	163	376	431	470	655	487
	Base 1980	159	309	367	428	607	421
Canada	Base 2000	163	361	432	391	689	524
	Base 1980	152	322	388	370	646	463
Japan	Base 2000	182	382	530	542	831	609
	Base 1980	203	352	403	493	749	538
Rest of the World	Base 2000	191	364	470	543	856	515
	Base 1980	187	293	394	438	713	460

Table 35. Consumption (mill. m^3) and prices ($/$m^3$) of logs and pulpwood in Base Scenarios 2000 and 1980.

		Consumption		Price	
Region	Scenario	Logs	Pulpwood	Logs	Pulpwood
Northern Europe	Base 2000	51.4	54.7	56	44
	Base 1980	53.3	53.9	58	40
Western Europe	Base 2000	72.8	53.3	66	52
	Base 1980	70.9	36.4	72	43
USA	Base 2000	253.8	247.3	38	37
	Base 1980	170.7	180.8	40	22
Canada	Base 2000	157.5	101.9	37	30
	Base 1980	118.9	63.9	30	22
Japan	Base 2000	82.6	37.1	62	61
	Base 1980	54.8	28.8	90	45
Rest of the World	Base 2000	524.9	144.2	44	44
	Base 1980	379.0	55.4	42	22
Total	Base 2000	1143.0	638.5		
	Base 1980	797.6	419.2		

Table 36. Production in Base Scenario 1980 (mill. m^3, mill. ton) and comparison with Base Scenario 1980. Technologies: T_1 = efficient technology of 1980, T_3 = new capacity.

		North. Europe	West. Europe	USA	Canada	Japan	Rest of World	Totals
Sawn-wood	T_1	23.9	39.6	75.3	41.9	37.1	210.6	
	T_3	.0	.0	46.7	12.1	17.0	54.5	
	Total	23.9	39.6	122.0	54.0	54.1	265.1	558.7
	Base 1980	24.9	39.6	75.3	42.8	37.1	213.7	433.4
Panels	T_1	4.3	21.3	27.7	4.8	10.2	33.6	
	T_3	.5	10.3	.0	6.0	3.6	58.8	
	Total	4.8	31.6	27.7	10.8	13.8	92.4	181.1
	Base 1980	4.4	21.3	27.7	4.8	8.0	33.8	100.0
Pulp	T_1	5.5	1.0	12.3	5.9	3.0	3.3	
	T_3	.8	.0	18.4	7.8	.0	12.8	
	Total	6.3	1.0	30.7	13.7	3.0	16.1	70.8
	Base 1980	6.5	1.0	20.7	5.9	3.0	6.5	43.6
News-print	T_1	1.8	1.1	3.3	4.9	1.5	2.3	
	T_3	.0	3.1	5.4	3.2	.3	8.6	
	Total	1.8	4.2	8.7	8.1	1.8	10.9	35.5
	Base 1980	2.9	1.5	4.2	10.6	2.7	5.2	27.1
Print-ing paper	T_1	2.2	4.2	6.6	.7	1.7	2.5	
	T_3	5.6	6.0	25.2	3.2	2.4	16.2	
	Total	7.8	10.2	31.8	3.9	4.1	18.7	76.5
	Base 1980	4.3	8.1	16.1	1.9	3.2	8.8	42.4
Pack-aging paper	T_1	2.9	6.6	27.6	1.9	3.4	5.2	
	T_3	.1	10.5	18.4	.8	9.3	20.8	
	Total	3.0	17.1	46.0	2.7	12.7	26.0	107.5
	Base 1980	3.2	11.7	38.9	3.1	8.8	7.3	73.0

Table 37. Trade flows (mill. m^3, mill. ton) for Base Scenario 2000 and comparison with total exports and imports of Base Scenario 1980. Rows refer to exporting and columns to importing regions. (Regions: 1 = Northern Europe, 2 = Western Europe, 3 = USA, 4 = Canada, 5 = Japan, 6 = Rest of the World).

(a) Logs

	1	2	3	4	5	6	Total	Base 1980
1							.0	1.3
2							.0	.0
3		6.0			18.0		24.0	14.6
4		4.0			12.0		16.0	3.5
5							.0	.0
6		5.2			38.8		44.0	32.2
Total	.0	15.2	.0	.0	68.8	.0	84.0	51.6
Base 1980	2.4	8.2	0.3	1.0	38.3	1.4	51.6	

(b) Pulpwood

	1	2	3	4	5	6	Total	Base 1980
1							.0	0.1
2							.0	.3
3					7.2		7.2	5.5
4		2.0			4.0		6.0	2.5
5							.0	.0
6							.0	18.9
Total	.0	2.0	.0	.0	11.2	.0	13.2	27.3
Base 1980	5.9	3.8	1.2	0.3	15.7	0.3	27.2	

(c) Sawnwood

	1	2	3	4	5	6	Total	Base 1980
1		12.0					12.0	15.8
2							.0	.9
3		12.0				14.1	26.1	6.7
4	2.1	12.0				25.0	39.0	29.5
5							.0	.0
6							.0	8.4
Total	2.1	36.0	.0	.0	.0	39.1	77.1	61.3
Base 1980	2.2	24.1	17.7	.1	8.4	8.8	61.3	

(d) Panels

	1	2	3	4	5	6	Total	Base 1980
1							.0	1.0
2							.0	.2
3							.0	2.2
4		5.3					5.3	1.4
5							.0	.1
6							.0	3.0
Total	.0	5.3	.0	.0	.0	.0	5.3	7.9
Base 1980	.3	2.8	1.0	0.6	2.7	.7	8.1	

(e) Pulp

	1	2	3	4	5	6	Total	Base 1980
1		2.3					2.3	3.6
2							.0	.2
3					.1		.1	4.1
4		6.5			2.3		7.8	1.8
5							.0	.0
6							.0	1.3
Total	.0	8.8	.0	.0	2.4	.0	11.2	11.0
Base 1980	.1	6.3	1.0	.0	1.2	2.3	10.9	

(f) Newsprint

	1	2	3	4	5	6	Total	Base 1980
1		1.0					1.0	3.1
2							.0	.0
3							.0	.2
4		1.0	2.0		2.0	2.0	7.0	9.6
5							.0	.0
6							.0	0.3
Total	.0	2.0	2.0	.0	2.0	2.0	8.0	13.2
Base 1980	1.0	3.5	6.8	.0	.0	1.9	13.2	

(g) Printing paper

	1	2	3	4	5	6	Total	Base 1980
1		4.0				2.0	6.0	3.2
2							.0	1.0
3		2.0			1.5	6.0	9.5	2.1
4		.6			1.5	.1	2.2	1.0
5							.0	.2
6							.0	.0
Total	.0	6.6	.0	.0	3.0	8.1	17.7	7.5
Base 1980	.1	4.3	.5	.1	.9	1.6	7.5	

(h) Packaging paper

	1	2	3	4	5	6	Total	Base 1980
1							.0	2.1
2							.0	1.7
3		3.0			3.0		6.0	6.3
4		.1					.1	2.0
5							.0	.1
6							.0	.2
Total	.0	3.1	.0	.0	3.0	6.1	12.4	12.4
Base 1980	1.2	4.6	.0	.9	.8	4.9	12.4	

7.2 Scenarios 6 and 7: Demand Level Variations

Recognizing that our estimates of the shifts in demand levels from 1980 to 2000 are highly uncertain, we have tested two alternative scenarios in which the level of demand is varied. Scenario 6 (high demand level) assumes that the shifts in demand would be twice as much as those summarized in Table 32. To support this increased demand, timber supply constraints for all but the European regions were relaxed by one-third as compared to Base Scenario 2000. This represents a *doubling* of timber supply from these regions as compared to Base Scenario 1980, making this scenario highly conjectural (but still useful for sensitivity analysis). Timber supply for the two European regions was again maintained at the 1980 level. Upper limits on investment in new capacity were unchanged from Base Scenario 2000, except that recycled paper processing capacity was increased at the same rate as the estimated increase in paper consumption. All other assmptions were the same as in Base Scenario 2000.

Scenario 7 (low demand level) assumes that the level of demand for all final products would be unchanged from 1980. All other assumptions are the same as in Base Scenario 1980.

Tables 38–41 summarize the results from these two scenario runs, with the figures from the 1980 and 2000 Base Scenarios provided for comparison.

As would be expected, consumption expands considerably for all products in Scenario 6. Consumption in Scenario 7 would drop back to roughly the level of the 1980 base, except that moderate shifts in consumption occur with respect to sawnwood. For this product, consumption increases in the European regions and Japan by comparison with 1980, and drops in North America.

Prices in general rise in Scenario 6 by comparison with Base 2000, whereas prices in Scenario 7 fall, except for sawnwood and panels in some regions, even by comparison with Base 1980. The latter result may be explained by the substantially increased timber supply base and the lifting of trade-flow restrictions.

Under the high demand level of Scenario 6, log and pulpwood prices would rise in all regions, with the largest increases in Japan and the rest of the world. The equating of log and pulpwood prices in the rest of the world (Table 40) is due to the fact that the supply of pulpwood in that region is insufficient to satisfy demand, so that about 14% of domestic log production is converted into pulpwood.

Log prices in Scenario 7 are modestly to substantially lower than in the Base 1980 scenario due to the increased timber supply. Pulpwood prices are stable or slightly reduced except in Japan and the rest of the world, where they show an increase compared to 1980. In the rest of the world this is caused by a major increase in pulpwood consumption. In Japan, however, pulpwood consumption actually declines by comparison with Base 1980. The pulpwood price increases in spite of this because of reduced domestic harvesting of large trees. The reduced log price in the rest of the world induces a large increase in log imports into Japan from that region, and this source of logs is substituted for the harvesting of

Table 38. Consumption (mill. m^3, mill. ton) in Scenarios 6 and 7 compared with the Base Scenarios.

Region	Scenario	Sawn-wood	Panels	Pulp	News-print	Printing paper	Packaging paper
Northern Europe	Scenario 6	15.7	6.2	3.6	1.0	2.4	3.7
	Base 2000	14.0	4.8	4.0	0.8	1.8	3.0
	Scenario 7	12.0	3.5	3.0	0.7	1.2	2.3
	Base 1980	11.4	3.5	3.0	0.7	1.2	2.3
Western Europe	Scenario 6	77.4	39.7	12.7	7.4	22.1	25.9
	Base 2000	75.6	31.6	9.7	6.2	16.7	20.2
	Scenario 7	69.0	24.4	4.4	5.1	11.5	14.6
	Base 1980	62.8	23.9	7.1	5.1	11.4	14.6
USA	Scenario 6	100.1	40.7	33.4	10.9	30.2	47.9
	Base 2000	95.9	33.0	30.6	10.7	22.3	40.0
	Scenario 7	82.1	26.8	19.6	10.9	14.6	32.5
	Base 1980	86.3	26.4	17.7	10.9	14.6	32.6
Canada	Scenario 6	16.1	7.1	10.9	1.2	2.5	3.3
	Base 2000	14.9	5.5	4.9	1.0	1.7	2.6
	Scenario 7	13.1	4.1	5.1	0.9	1.0	2.0
	Base 1980	13.4	3.9	4.1	0.9	1.0	2.0
Japan	Scenario 6	58.0	16.9	8.9	5.0	10.3	21.9
	Base 2000	54.1	13.8	5.4	3.8	7.1	15.7
	Scenario 7	47.5	10.9	3.0	2.8	4.0	9.5
	Base 1980	45.5	10.4	4.2	2.7	4.0	9.6
Rest of the World	Scenario 6	384.8	153.5	30.7	19.4	43.4	39.9
	Base 2000	304.2	92.4	16.1	12.9	26.8	26.0
	Scenario 7	214.1	31.5	8.9	6.7	10.4	11.9
	Base 1980	214.1	31.5	7.6	6.8	10.4	12.0
Total	Scenario 6	652.1	264.1	100.2	44.9	110.9	142.6
	Base 2000	558.7	181.1	70.7	35.4	76.4	107.5
	Scenario 7	437.8	101.2	44.0	27.2	42.7	72.9
	Base 1980	433.5	99.6	43.7	27.1	42.6	73.1

Table 39. Prices ($/m^3, $/ton) in Scenarios 6 and 7 compared with the Base Scenarios.

Region	Scenario	Sawn-wood	Panels	Pulp	News-print	Printing paper	Packaging paper
Northern Europe	Scenario 6	205	372	485	445	650	602
	Base 2000	186	370	474	439	643	593
	Scenario 7	182	308	373	415	599	542
	Base 1980	235	298	454	485	707	560
Western Europe	Scenario 6	237	378	524	554	812	631
	Base 2000	200	375	513	545	804	619
	Scenario 7	196	322	412	514	730	588
	Base 1980	248	344	456	533	761	586
USA	Scenario 6	181	397	435	475	659	493
	Base 2000	163	376	431	470	655	487
	Scenario 7	173	298	366	422	604	428
	Base 1980	159	309	367	428	607	421
Canada	Scenario 6	181	372	443	397	600	535
	Base 2000	163	361	432	391	689	524
	Scenario 7	159	300	331	345	606	450
	Base 1980	152	322	388	370	646	463
Japan	Scenario 6	204	405	534	562	840	630
	Base 2000	182	382	530	542	831	609
	Scenario 7	183	322	419	472	746	566
	Base 1980	203	352	403	493	749	538
Rest of the World	Scenario 6	209	376	551	542	804	535
	Base 2000	191	364	497	543	856	515
	Scenario 7	187	293	420	456	709	485
	Base 1980	187	293	394	438	713	460

Table 40. Log and pulpwood consumption (mill. m^3) and price ($/$m^3$) in Scenarios 6 and 7 compared with the Base Scenarios.

Region	Scenario	Consumption		Price	
		Logs	Pulpwood	Logs	Pulpwood
Northern Europe	Scenario 6	52.1	59.3	59	46
	Base 2000	51.4	54.7	56	44
	Scenario 7	51.2	47.0	54	39
	Base 1980	53.3	53.9	58	40
Western Europe	Scenario 6	74.4	65.6	71	56
	Base 2000	72.8	53.3	66	52
	Scenario 7	70.9	34.0	64	43
	Base 1980	70.9	36.4	72	43
USA	Scenario 6	316.1	311.4	49	38
	Base 2000	253.8	247.3	38	37
	Scenario 7	172.9	181.3	38	22
	Base 1980	170.7	180.8	40	22
Canada	Scenario 6	215.3	139.8	49	32
	Base 2000	157.5	101.9	37	30
	Scenario 7	123.8	58.1	32	17
	Base 1980	118.9	63.9	30	22
Japan	Scenario 6	85.6	50.4	82	74
	Base 2000	82.6	37.1	62	61
	Scenario 7	60.0	25.7	60	46
	Base 1980	54.8	28.8	90	45
Rest of the World	Scenario 6	657.8	250.0	56	56
	Base 2000	524.9	144.2	44	44
	Scenario 7	378.6	77.8	42	28
	Base 1980	379.0	55.4	42	22
Total	Scenario 6	1401.3	876.5		
	Base 2000	1143.0	627.1		
	Scenario 7	857.4	423.9		
	Base 1980	847.6	419.2		

Table 41. Production (mill. m^3, mill. ton) in Scenarios 6 and 7 compared with the Base Scenarios.

Region	Scenario	Sawn-wood	Panels	Pulp	News-print	Printing paper	Packaging paper
Northern Europe	Scenario 6	23.9	6.2	6.9	2.0	6.4	3.7
	Base 2000	23.9	4.8	6.3	1.8	7.8	3.0
	Scenario 7	23.9	4.3	5.5	1.7	5.2	2.9
	Base 1980	24.9	4.4	6.5	2.9	4.3	3.2
Western Europe	Scenario 6	39.6	39.7	1.0	5.4	14.1	19.9
	Base 2000	39.6	31.6	1.0	4.2	10.2	17.1
	Scenario 7	39.6	21.3	1.0	3.1	4.2	7.7
	Base 1980	39.6	21.3	1.0	2.3	8.1	11.7
USA	Scenario 6	152.5	33.7	41.6	8.9	33.7	54.4
	Base 2000	122.0	27.7	30.7	8.7	31.8	46.0
	Scenario 7	76.5	27.7	19.6	8.9	16.6	38.8
	Base 1980	75.3	27.7	20.7	4.2	16.1	38.9
Canada	Scenario 6	73.0	16.1	18.9	6.2	12.0	5.8
	Base 2000	54.0	10.8	13.7	8.1	3.9	2.7
	Scenario 7	44.7	4.8	5.9	5.2	3.9	5.0
	Base 1980	42.8	4.8	5.9	10.6	1.9	3.1
Japan	Scenario 6	58.0	12.5	3.0	3.0	7.3	18.9
	Base 2000	54.1	13.8	3.0	1.8	4.1	12.7
	Scenario 7	39.1	10.2	3.0	1.5	2.3	6.4
	Base 1980	37.1	8.0	3.0	2.7	3.2	8.8
Rest of the World	Scenario 6	305.1	155.9	28.7	19.4	37.4	39.9
	Base 2000	265.1	92.4	16.1	10.9	18.7	26.0
	Scenario 7	214.0	33.0	8.9	6.7	10.4	11.9
	Base 1980	213.7	33.8	6.5	5.2	8.8	7.3
Total	Scenario 6	652.1	264.1	100.1	44.9	110.9	142.6
	Base 2000	558.7	181.1	70.8	35.5	76.5	107.5
	Scenario 7	437.8	170.3	43.9	27.1	42.6	72.7
	Base 1980	433.4	100.0	43.6	27.9	42.4	73.0

large trees domestically. Therefore the relatively cheap pulpwood that would have been produced as a residual of large-tree harvest must come from a 20% increase in the more expensive small-tree harvest.

Total production in Scenario 6 increases substantially as compared to the base scenarios in order to satisfy the very high level of demand. The bulk of this increase, however, goes to North America and to the rest of the world (especially the latter, where a large share of the increased demand resides).

Trade flow matrices for Scenario 6 (not included with this paper) show a major increase in exports of sawnwood and pulp from North America as compared to Base Scenario 2000. Other changes in trade are less significant.

Scenario 7 indicates reduced trade in most commodities by comparison with Base Scenario 1980 (ie., a larger part of consumption is produced domestically). However, exports of logs and pulpwood from North America and from the rest of the world would increase because of the increased timber supply there.

7.3 Scenario 8: Import Tariffs

A perennially important topic with respect to the analysis of international trade is the effect of protective tarrifs and other trade barriers or incentives. To investigate the possible effect of tariffs, we devised Scenario 8 to reflect a 20% tariff on imports of all commodities into Western Europe and into the rest of the world. As a surrogate for an exact tariff on the value of the commodities traded, we increased transportation costs to these two regions from all other regions by 20% of the *reference* prices in 1980 (see Table 3 and 9 for summaries of these reference prices; the basic transportation costs are summarized in Table 17). All other assumptions for this scenario are the same as those for Base Scenario 2000.

Tables 42–45 summarize the results of Scenario 8. As one would expect, consumption in the two protected regions declines as compared to Base Scenario 2000, and prices in those regions rise. The only apparent anomaly is in pulp consumption in Western Europe, which increases by about 20%. This is due to increased domestic production of printing paper and packaging to replace imports of these commodities from North America, which are now more expensive. Except for pulp, consumption in other regions is relatively unchanged by comparison with Base 2000. However, prices generally are driven down in all of the non-tariff regions. The only exceptions are in Japanese sawnwood and panels, where prices increase because of the higher cost of logs from the rest of the world.

Table 42. Consumption (mill. m^3, mill. ton) for Scenario 8 and comparison with Base Scenario 2000.

Region	Scenario	Sawn-wood	Panels	Pulp	News-print	Printing paper	Packaging paper
Northern Europe	Scenario 8	14.4	4.8	3.7	0.8	1.8	3.0
	Base 2000	14.0	4.8	4.0	0.8	1.8	3.0
Western Europe	Scenario 8	73.1	31.3	11.7	6.1	16.6	20.1
	Base 2000	75.6	31.6	9.7	6.2	16.7	20.2
USA	Scenario 8	97.1	33.4	28.8	10.7	22.3	40.0
	Base 2000	95.9	33.0	30.6	10.7	22.3	40.0
Canada	Scenario 8	15.7	5.5	4.8	1.1	1.8	2.6
	Base 2000	14.9	5.5	4.9	1.0	1.7	2.6
Japan	Scenario 8	53.9	13.7	5.4	3.8	7.1	15.7
	Base 2000	54.1	13.8	5.4	3.8	7.1	15.7
Rest of the World	Scenario 8	298.5	92.2	16.1	12.7	26.7	25.9
	Base 2000	304.2	92.4	16.1	12.9	26.8	26.0
Total	Scenario 8	557.8	180.9	70.5	35.2	76.3	107.3
	Base 2000	558.7	181.1	70.7	35.4	76.4	107.5

Table 43. Prices ($/$m^3$, $/ton) for Scenario 8 and comparison with Base Scenario 2000.

Region	Scenario	Sawn-wood	Panels	Pulp	News-print	Printing paper	Packaging paper
Northern Europe	Scenario 8	159	367	451	433	633	584
	Base 2000	186	370	474	439	643	593
Western Europe	Scenario 8	218	384	586	576	851	649
	Base 2000	200	375	513	545	804	619
USA	Scenario 8	159	367	423	468	650	485
	Base 2000	163	376	431	470	655	487
Canada	Scenario 8	146	352	412	379	649	513
	Base 2000	163	361	432	391	689	524
Japan	Scenario 8	184	393	510	536	816	604
	Base 2000	182	382	530	542	831	609
Rest of the World	Scenario 8	203	372	533	611	944	529
	Base 2000	191	364	497	543	856	515

Table 44. Log and pulpwood consumption (mill. m^3) and prices ($/$m^3$) for Scenario 8 and comparison with Base Scenario 2000.

Region	Scenario	Consumption		Price	
		Logs	Pulpwood	Logs	Pulpwood
Northern Europe	Scenario 8	51.4	50.0	52	43
	Base 2000	51.4	54.7	56	44
Western Europe	Scenario 8	72.8	67.9	69	64
	Base 2000	72.8	53.3	66	52
USA	Scenario 8	242.9	232.5	35	35
	Base 2000	253.8	247.3	38	37
Canada	Scenario 8	154.1	101.2	30	26
	Base 2000	157.5	101.9	37	30
Japan	Scenario 8	58.5	37.2	70	60
	Base 2000	82.6	37.1	62	61
Rest of the World	Scenario 8	557.2	144.1	52	52
	Base 2000	524.9	144.2	44	44
Total	Scenario 8	1136.9	632.9		
	Base 2000	1143.0	627.1		

Table 45. Production (mill. m^3, mill. ton) for Scenario 8 and comparison with Base Scenario 2000.

Region	Scenario	Sawn-wood	Panels	Pulp	News-print	Printing paper	Packaging paper
Northern Europe	Scenario 8	23.9	4.8	5.5	1.8	7.1	3.0
	Base 2000	23.9	4.8	6.3	1.8	7.8	3.0
Western Europe	Scenario 8	39.6	31.3	3.6	4.1	12.6	20.1
	Base 2000	39.6	31.6	1.0	4.2	10.2	17.1
USA	Scenario 8	115.9	27.7	28.8	8.7	29.8	43.0
	Base 2000	122.0	27.7	30.7	8.7	31.8	46.0
Canada	Scenario 8	50.7	14.0	13.6	7.9	3.9	2.6
	Base 2000	54.0	10.8	13.7	8.1	3.9	2.7
Japan	Scenario 8	37.1	10.9	3.0	1.8	4.1	12.7
	Base 2000	54.1	13.8	3.0	1.8	4.1	12.7
Rest of the World	Scenario 8	285.4	92.2	16.1	10.9	18.7	25.9
	Base 2000	265.1	92.4	16.1	10.9	18.7	26.0
Total	Scenario 8	552.6	180.9	70.6	35.2	76.2	107.3
	Base 2000	558.7	181.1	70.8	35.5	76.5	107.5

7.4 Scenario 9: Increased USA Timber Supply

The final scenario investigated in this analysis simulates a hypothetical increase in timber supply in the USA. For this scenario we assumed that the year 2000 timber supply in the USA would be twice that of 1980, thus representing an increase of one-third as compared to the Base 2000 scenario. Timber supplies in all other regions were held constant at the Base 2000 level, and all other assumptions were the same as for Base 2000. The results of the analysis for this scenario are summarized in Tables 46–49.

Overall consumption of forest products is not influenced greatly by this scenario as compared to Base 2000, although there is a slight increase in consumption for all products. The increase is most pronounced in the USA, with smaller increases in consumption for the other regions. Prices, however, show larger changes, particularly for pulp and, to a lesser extent, paper products.

Consumption of logs and pulpwood, except in the USA and Japan, is either stable or declines. Pulpwood consumption in Canada declines substantially, with a similar large drop in price. All log and pulpwood prices decline significantly.

Production of sawnwood and panels is relatively stable in this scenario as compared to Base 2000, with increases in North American and Japanese sawnwood production supplying the increased consumption of this product. Sawnwood production in the rest of the world would be reduced, with imported sawnwood from North America supplying the slightly increased demand in that region. Panel production in Canada would decline substantially, being supplanted by increased US production. Pulp production would become cheaper in the USA than either Northern Europe or Canada, so that the pulp industry in both of those countries would lose markets to the USA. The United States would also increase production of all paper grades, to the detriment of Western Europe in printing paper and of both European regions in packaging. Japan's production of printing paper would expand considerably to utilize cheap pulpwood from the USA, and Canada's advantageous location would allow it to import cheap pulp from the USA, thus permitting a major expansion in packaging production.

Table 46. Consumption (mill. m^3, mill. ton) for Scenario 9 and comparison with the Base Scenario 2000.

Region	Scenario	Sawn-wood	Panels	Pulp	News-print	Printing paper	Packaging paper
Northern Europe	Scenario 9	14.0	4.8	4.1	0.8	1.8	3.0
	Base 2000	14.0	4.8	4.0	0.8	1.8	3.0
Western Europe	Scenario 9	75.6	31.6	8.4	6.3	16.8	20.3
	Base 2000	75.6	31.6	9.7	6.2	16.7	20.2
USA	Scenario 9	97.7	33.4	31.0	11.0	22.6	40.5
	Base 2000	95.9	33.0	30.6	10.7	22.3	40.0
Canada	Scenario 9	15.1	5.5	5.7	1.1	1.8	2.7
	Base 2000	14.9	5.5	4.9	1.0	1.7	2.6
Japan	Scenario 9	54.2	13.8	6.4	3.9	7.2	15.8
	Base 2000	54.1	13.8	5.4	3.8	7.1	15.7
Rest of the World	Scenario 9	306.8	92.5	16.1	13.1	26.9	26.0
	Base 2000	304.2	92.4	16.1	12.9	26.8	26.0
Total	Scenario 9	563.4	181.6	71.7	36.2	77.1	107.8
	Base 2000	558.7	181.1	70.7	35.4	76.4	107.5

Table 47. Prices ($/$m^3$, $/ton) for Scenario 9 and comparison with the Base Scenario 2000.

Region	Scenario	Sawn-wood	Panels	Pulp	News-print	Printing paper	Packaging paper
Northern Europe	Scenario 9	180	367	418	427	619	556
	Base 2000	186	370	474	439	643	593
Western Europe	Scenario 9	200	372	457	530	771	601
	Base 2000	200	375	513	545	804	619
USA	Scenario 9	157	366	368	432	609	442
	Base 2000	163	376	431	470	655	487
Canada	Scenario 9	157	359	376	358	645	491
	Base 2000	163	361	432	391	689	524
Japan	Scenario 9	181	382	467	522	785	590
	Base 2000	182	382	530	542	831	609
Rest of the World	Scenario 9	185	361	482	510	786	509
	Base 2000	191	364	497	543	856	515

Table 48. Log and pulpwood consumption (mill. m^3) and price ($/$m^3$) for Scenario 9 and comparison with the Base Scenario 2000.

Region	Scenario	Consumption		Price	
		Logs	Pulpwood	Logs	Pulpwood
Northern Europe	Scenario 9	51.4	50.9	52	42
	Base 2000	51.4	54.7	56	44
Western Europe	Scenario 9	72.9	50.9	63	50
	Base 2000	72.8	53.3	66	52
USA	Scenario 9	269.8	281.0	29	22
	Base 2000	253.8	247.3	38	37
Canada	Scenario 9	157.5	77.4	32	20
	Base 2000	157.5	101.9	37	30
Japan	Scenario 9	82.8	38.0	60	56
	Base 2000	82.6	37.1	62	61
Rest of the World	Scenario 9	519.7	144.2	41	41
	Base 2000	524.9	144.2	44	44
Total	Scenario 9	1154.1	642.4		
	Base 2000	1143.0	627.1		

Table 49. Production (mill. m^3, mill. ton) for Scenario 9 and comparison with the Base Scenario 2000.

Region	Scenario	Sawn-wood	Panels	Pulp	News-print	Printing paper	Packaging paper
Northern Europe	Scenario 9	23.9	4.8	5.5	1.8	8.0	2.9
	Base 2000	23.9	4.8	6.3	1.8	7.8	3.0
Western Europe	Scenario 9	39.6	31.6	1.0	4.3	8.8	14.3
	Base 2000	39.6	31.6	1.0	4.2	10.2	17.1
USA	Scenario 9	126.8	33.4	38.0	9.0	32.1	47.2
	Base 2000	122.0	27.7	30.7	8.7	31.8	46.0
Canada	Scenario 9	57.2	5.5	8.1	8.2	3.9	5.2
	Base 2000	54.0	10.8	13.7	8.1	3.9	2.7
Japan	Scenario 9	54.2	13.8	3.0	1.9	5.5	12.8
	Base 2000	54.1	13.8	3.0	1.8	4.1	12.7
Rest of the World	Scenario 9	261.8	92.5	16.1	10.9	18.7	26.0
	Base 2000	265.1	92.4	16.1	10.9	18.7	26.0
Total	Scenario 9	563.5	181.6	71.7	36.1	77.0	108.4
	Base 2000	558.7	181.1	70.8	35.5	76.5	107.5

8. COMPUTATIONAL CONSIDERATIONS

For this preliminary version of the **GTM**, the single-period optimization problem given by Eqs. (8)–(11) comprises 432 decision variables (72 for each of the six regions), and 54 constraints (nine per region). Of the 72 variables per region, two nonlinear variables (y_{im}) are used to model the harvesting of large and small trees; one linear variable measures the quantity of excess production of pulpwood, if any; five nonlinear variables (c_{ik}) determine the consumption of each of the five final products (sawnwood, panels, newsprint, printing paper, and packaging paper); 19 linear variables (y_{im}) are used to model the conversion of raw materials into final products; and 45 linear variables (e_{ijk}) model the export of the nine commodities (Table 1) from the producing region to the other five regions. The nine constraints per region are all linear as indicated in Eq. (9). Capacity and trade-flow limits as specified by Eqs. (10) and (11) are handled by bounds on the production and trade variables, rather than by explicit constraints.

The model was implemented on IIASA's VAX 11/780 minicomputer by utilizing a nonlinear programming system called MINOS (Murtagh and Saunders 1977 and 1978). MINOS was developed to permit the solution of large mathematical programming problems which may include nonlinear terms in the objective function and/or constraints. It combines an efficient and reliable implementation of the revised simplex method of linear programming (Dantzig 1963) with a reduced-gradient approach (Wolfe 1967) for dealing with nonlinearities in the objective function. When the problem includes nonlinear constraints, MINOS additionally employs a projected augmented Lagrangian algorithm (Murtagh and Saunders 1980). FORTRAN subroutines must be provided by the user for the evaluation of the nonlinear functions and gradients.

Table 50 shows the number of iterations and computing times required to find the equilibrium solutions for the nine scenarios considered in this analysis. Note that Scenarios 4 (dollar revaluation) and 8 (import tariffs) required more iterations than other scenarios, whereas the minimum-cost solution (Scenario 2) was found most quickly. Computing times shown include input/output time as well as solution time.

Table 50. Central processing unit (CPU) times and iterations required to find equilibrium solutions for the nine scenarios considered in this paper.

Scenarios	CPU time, s	Iterations
1	198	601
2	99	393
3	168	541
4	228	744
5	236	646
6	273	677
7	204	540
8	256	735
9	213	575

All of the solutions reported here were obtained from a "cold start." In the full-scale verson of the **GTM**, however, the solution for period t will be used as the starting solution for period $t+1$. This should significantly reduce computation times for subsequent periods.

9. CONCLUDING REMARKS

As a result of our experience with the preliminary version of the **GTM** reported in this paper, we are satisfied that a full-scale model can be developed which will satisfactorily depict the forest sector of the global economy and will be capable of accurately assessing possible long-term structural changes in that sector. We make no claim that the preliminary model can be used for this purpose, first because of the high degree of aggregation we have used (particularly with respect to the region we have called "the rest of the world"); and second because much of the data used in the preliminary model are at best very tentative. In spite of this, we believe that the development of the preliminary version of the **GTM** has been a useful exercise. First, our experience with the model suggests that it is computationally efficient and numerically stable. Second, even though the data used in this version of the **GTM** are of inadequate quality, all of the scenario runs made with the model produce results which are fully consistent with our understanding of the forest sector. Thus we are able to conclude that the spatial equilibrium model satisfactorily depicts the structure of the forest sector of the global economy.

In transferring what we have learned from this preliminary model to the development of the full-scale **GTM**, the following points are of particular importance:

- The most critical need lies with the acquisition of valid data for all regions. For this we are relying heavily on more than 100 collaborators worldwide. The contribution of these collaborators is thus of critical importance to the development of a model capable of serving as a fully satisfactory abstraction of the forest sector.
- The dynamic structure of the **GTM**, which has been mostly ignored in this paper, must receive major emphasis. The questions of how to project shifts in demand levels, how to model expansion of capacity and changes in technological coefficients over time, and how to treat changing inertial effects in trade flows are all important considerations that must be addressed.
- Software for manipulating the database and for updating timber supply information during model runs are currently under development and must be given continued emphasis.
- Development of a range of scenario questions to be addressed by the **GTM** is of fundamental importance, and we will continue to seek the advice of interested parties in an effort to identify scenarios that will be of interest to the widest possible clientele.

As a final comment, we emphasize once again that the results reported in this paper are *not* to be taken as significant in a quantitative sense. We have described the results of the scenario runs in some detail only for the purpose of demonstrating that they are consistent with economic theory. The results suggest that the model can serve as a satisfactory abstraction of the forest sector of the global economy. Specific quantitative results, however, will have to await the development of the full-scale model.

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