Working Paper

A MODEL OF INTERNATIONAL TRADE OF FOREST PRODUCTS (GTM-1)

Joseph Buongiorno
James K. Gilless

July 1983
WP-83-63

The Forest Sector Project
International Institute for Applied Systems Analysis
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in collaboration with

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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 forestry 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 of wood products. Such issues include the development of the global economy and population, new wood products and substitution for wood products, future supply of roundwood and alternative fiber sources, technology development 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 describes a preliminary version of a global model for studying international trade in wood products. The trade mechanism is based on the economic equilibrium concept appended by features accounting for inertia and trade barriers. The methodology is illustrated for trade in newsprint and for a relatively aggregated set of world regions.

Markku Kallio
Project Leader
Forest Sector Project

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INTRODUCTION

The objective of this paper is to describe a method of modeling the international trade of forest products. An application of this method to the trade of newsprint between major importers and exporters is also reported.

This work is part of a broader project within the International Institute for Applied Systems Analysis (IIASA) to develop a model of the world forestry sector. That project consists of two elements. First, the analysis and modeling of the forestry sector within IIASA member countries. Second, the development of a system capable of linking the individual component models. The purpose of this linkage system is to insure that forecasts or plans of any individual country are compatible with those of other countries (Adams et al. 1982; Batten et al. 1983).

Since the essential relationship between national forest sectors consists of exchanges of forestry-based commodities, development of an international linkage system boils down to the modeling of forest products trade. In that context, consistency of individual country forecasts requires, among other things, that total world imports balance total world exports for each commodity. Also, the CIF price that a specific country expects to pay for a commodity must be consistent with the world demand and supply for that commodity.

It is to the solution of this international trade problem that the present paper is addressed. In any modeling exercise of this type three factors are necessary for success: conceptualization, data, and software. Among these, data is probably the most important and often the most neglected. But one should not underestimate the resources necessary to program and test the software for large models. The importance of conceptualization is often exaggerated. In applied work it is not a bad idea to stick to well-known theories and concepts. For one thing this facilitates communication among members of multidisciplinary teams and between the research team and its clients.

For that reason the model of international forest products trade suggested here (GTM-1), uses well-known concepts of economic theory, proven methods of operation research, and previously tested software. It is also designed to keep data requirements to a manageable level.

MODEL PRINCIPLES

The model structure was adapted from that developed recently by the authors for the pulp and paper sector of North America (Buongiorno 1981, Buongiorno and Gilless 1982, Gilless and Buongiorno 1983). In that model the problem of linkage had also to be solved since North America was divided into 11 regions, and the trade within North America and between North America, Western Europe, Japan and the rest of the world was recognized explicitly.

In some respects, the model presented here is a simplification of the pulp and paper sector model. The former model used activity analysis to represent supply, demand, and production costs in regions where data permitted. In other regions demand and supply were modeled using simple econometric relationships. Only the second approach is used here. Also, changes in manufacturing capacity are not modeled, this being the task of individual country teams. Instead, attention is given to the minimum information that must be available from each individual country to make the international linkage possible. In addition, new features have been introduced to represent barriers to trade and inertia of trade adjustments.

The fundamental assumption underlying this trade model is that the major forces governing international exchanges of forest products can be represented by the classical model of a competitive market. Nevertheless, some constraints must be accounted for. These include tariffs, quotas and the inertia of market mechanisms. Also, transport costs between exporting and importing countries must be recognized.

Within these constraints the model depicts world market forces leading to a general equilibrium in which demand for imports in any given country balances the supply of exports to that country from the rest of the world at a certain CIF price (Figure 1). Symmetrically, in any exporting country, the FOB export price is such that the country's exports balances the demand for imports from that country by the rest of the world.

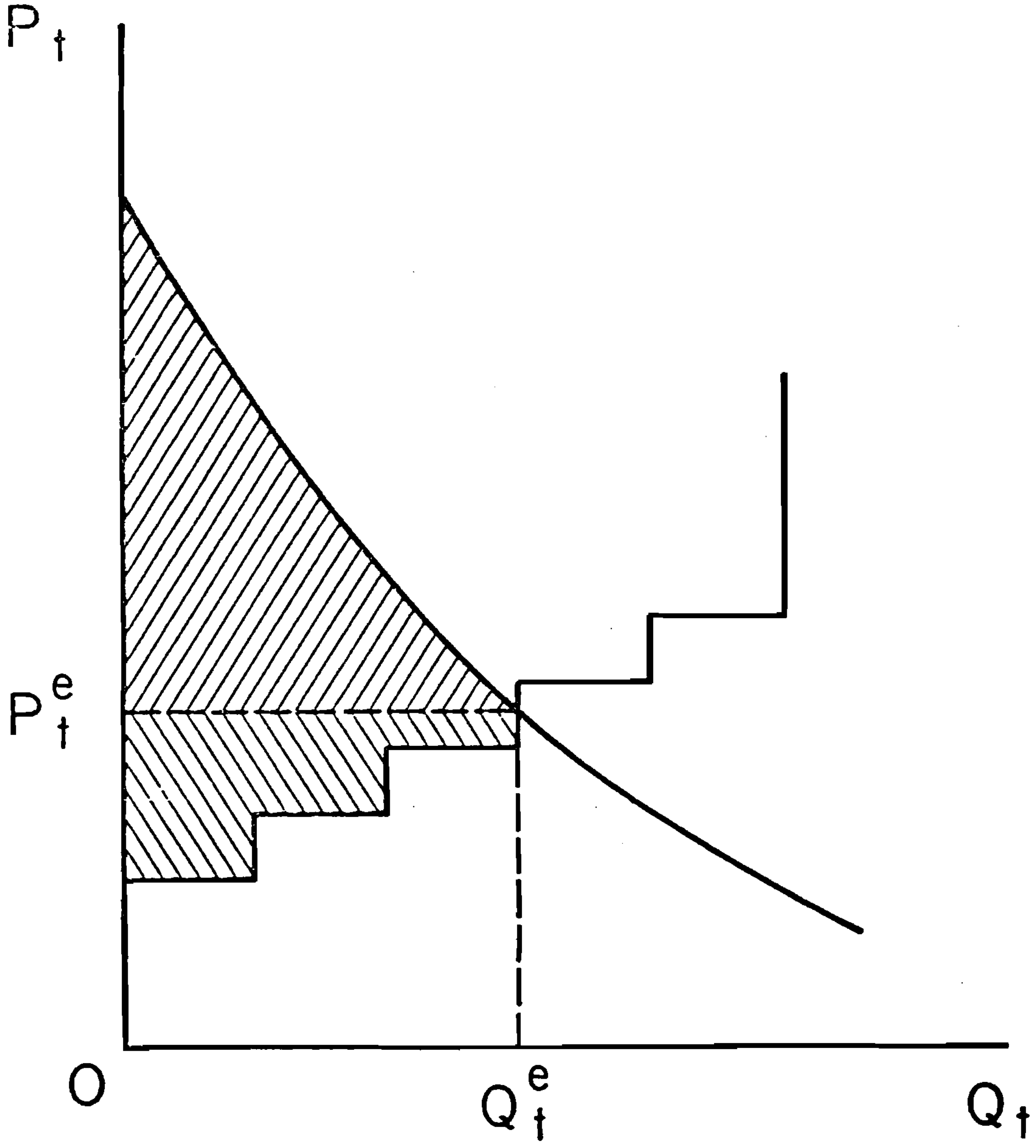

Figure 1. The forest products trade model determines equilibrium imports and exports and corresponding prices by maximizing the surplus value of trade (shaded area), for all countries simultaneously.

Following Samuelson (1952), the quantities that are exchanged, and the prices at which these exchanges take place, are obtained by solving a mathematical programming problem. The objective function of this maximization problem is the surplus value of trade. For any one country this surplus value corresponds to the grey area in Figure 1. The surplus value of all trade is the sum of the surplus value for all countries considered. The constraints of the mathematical programming problem define import and export functions, trade barriers and inertia.

Given a procedure to calculate equilibrium prices and quantities in any year one then needs a method to represent the relationship between equilibria over time (Figure 2). One possible approach would be to assume an inter-temporal equilibrium. That is to say, prices and quantities in any year would be obtained by maximizing the surplus value of trade over the entire forecasting period. This approach, although considered for a time was abandoned for two reasons. First, the resulting optimization problem is extremely large and cumbersome. Second and most importantly, it does not seem plausible to assume that markets fit the perfectly competitive paradigm over a very long time horizon. On the contrary, one must recognize that agents operating in those markets can forecast accurately only over a very short time period. It also seems reasonable to assume that these forecasts and the decisions they lead to are mostly influenced by events of the recent past. For these reasons, we have constructed the model to calculate an annual equilibrium by maximizing the surplus value of trade in that year. However, the position of the demand and supply schedules in any year may be a function of the equilibrium solution in the previous year (Figure 2).

COMPUTATION OF EQUILIBRIUM SOLUTIONS

The model describing the balance between total imports and exports, and the corresponding CIF and FOB prices of the set of forest-based commodities of interest, in any given year, is described by a linear program.

The objective function of this program measures the surplus value of trade and has the following expression (all variables and parameters are defined in Table 1):

$$\max Z = Z_D - Z_S - Z_T \tag{1}$$

where

$$Z_D = \sum_{\substack{i \in ID_k \\ k \in IC}} V(D_{ik})$$

$$Z_S = \sum_{i \in IS_k} C(S_{ik})$$

$$Z_T = \sum_{\substack{i \in I_{jk} \\ j \in J_{ik} \\ k \in IC}} T_{ijk} \cdot CT_{ijk}$$

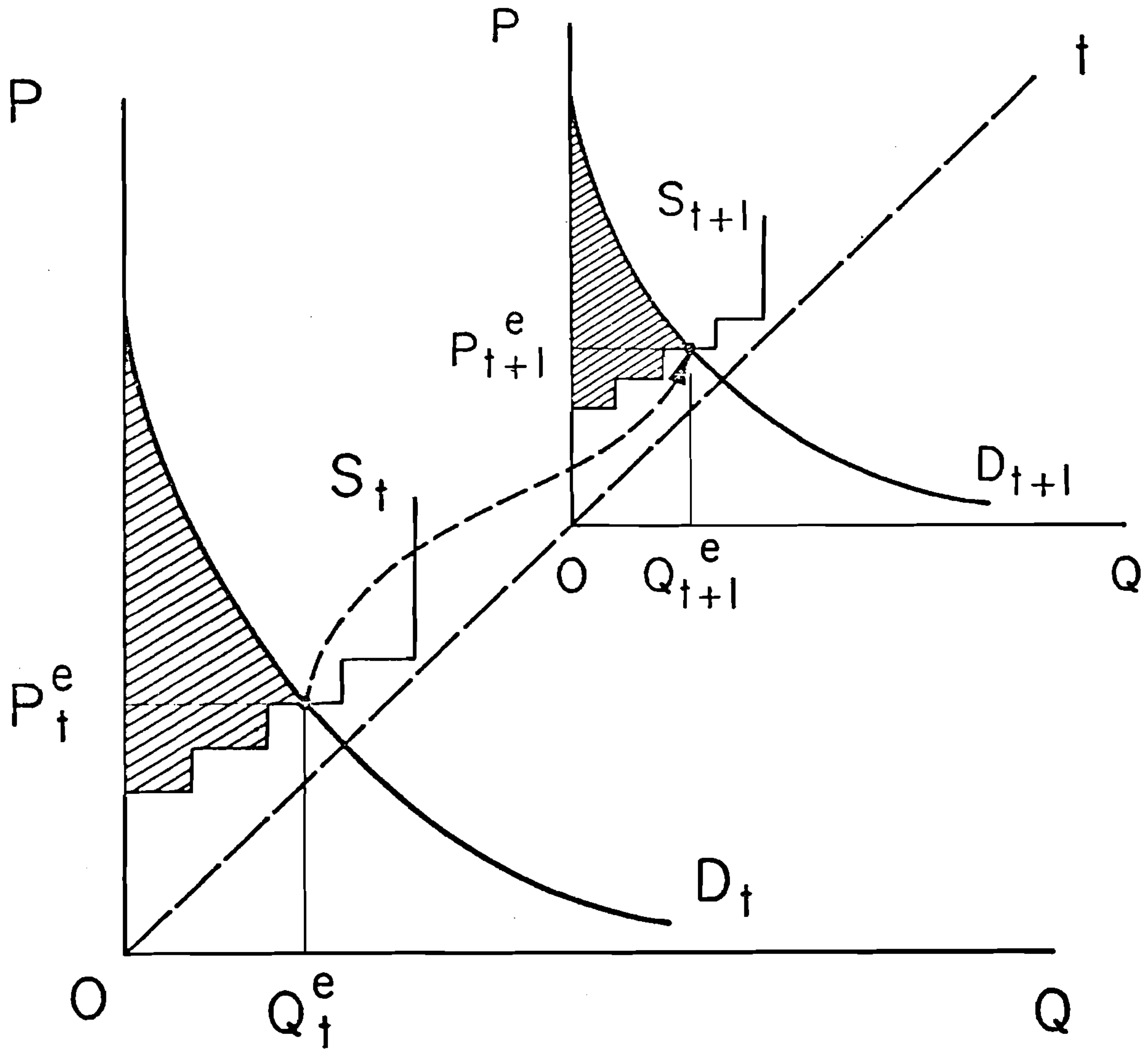

Figure 2. World trade equilibria are computed for every year in the projection period. The position of import, and export schedules in a given year (t + 1) is a function of exogenous shifters and of lagged endogenous variables determined by the previous year's (t) equilibrium solution.

Table 1. Variables and parameters used in model.

Subscripts:

i,j	regions
k	commodities
m	shifters
t	year

Variables:

D_{ik}	quantity of commodity k imported by region i
P_{ik}	price of commodity k in region i
S_{ik}	quantity of commodity k exported by region i
T_{ijk}	quantity of commodity k exported from region i to region j
Y_m	shift variable m
Z	surplus value of trade
Z_S	area under all export functions
Z_D	area under all demand functions
Z_T	sum of all transport costs

Functions:

$V(\cdot)$	area under a demand curve up to the quantity argument
$C(\cdot)$	area under a supply curve up to the quantity argument

Sets:

E_{jk}	set of regions upon which a joint import quota for commodity k is placed by region j
I_{jk}	set of regions which can export commodity k to region j
IC	set of commodities
ID_k	set of regions that are importers of commodity k
IS_k	set of regions that are exporters of commodity k
IQ_k	set of regions placing import quotas on commodity k
J_{jk}	set of regions which can import commodity k from region i

Parameters:

α_{ij}	inertia parameter for exports from region i to region j
ρ	price elasticity of demand
τ	price elasticity of supply
ω_m	elasticity of demand with respect to shift variable m
ω_0	shift parameter of demand with respect to time
CT_{ijk}	cost of transportation per unit of commodity k from region i to region j
S^X	upper limit on supply
Q_{jk}^X	quota on imports of commodity k imposed by region j.

i.e., Z_D measures the area under all the import demand functions, Z_S measures the area under all export supply functions, Z_T refers to total transportation costs. For any given country, import and (or) export functions can be replaced by total national demand and supply functions without affecting the solution. However, in the remainder of the paper it is assumed that only import and export functions are used.

In general, the function V and C are not linear. To apply the linear programming algorithm, they are approximated using the convex separable programming method of Duloy and Norton (1975).

One set of constraints used in the model insures that the total amount of a particular commodity supplied by a country balances the amount shipped by that country to its clients. There is a constraint of this type for each commodity and for each country exporting that commodity, i.e.,

$$S_{ik} - \sum_{j \in J_{ik}} T_{ijk} \geq 0 \qquad k \in IC,\ i \in IS_k \tag{2}$$

Another set of constraints is used to represent the balance between the quantities shipped by various suppliers to a particular country and the total imports of that country. One constraint of this type is needed for each importer and commodity, namely,

$$\sum_{i \in I_{ik}} T_{ijk} - D_{jk} \geq \qquad k \in IC,\ j \in ID_k \tag{3}$$

For any specific country and commodity, the demand for import and/or supply of export functions are defined by the price and quantity at the beginning of the year of interest and by price elasticities.

More precisely, the slopes of linear approximations to the import and export functions are calculated as follows:

$$\frac{\Delta D}{\Delta P} = \rho \frac{D_0}{P_0}, \qquad -\infty < \rho < 0 \tag{4}$$

$$\frac{\Delta S}{\Delta P} = \tau \frac{S_0}{P_0}, \qquad S \leq S^X,\ 0 < \tau \leq \infty \tag{5}$$

where prices in (4) and (5) are import CIF and export FOP prices, respectively, and the subscript 0 refers to equilibrium prices and quantities at the beginning of the year of interest.

Figure 3 shows the different export functions allowed by equation (5). The elasticities and price-quantity points in equations (4) and (5), together with transport costs in equation (1) are all that is needed to calculate the equilibrium pattern of trade brought about by pure market forces in any given year. However, other factors may influence the equilibrium solution. These include tariffs, quotas and specific trade arrangements. How these barriers to trade are handled in the model will be discussed after presenting its essential dynamic features.

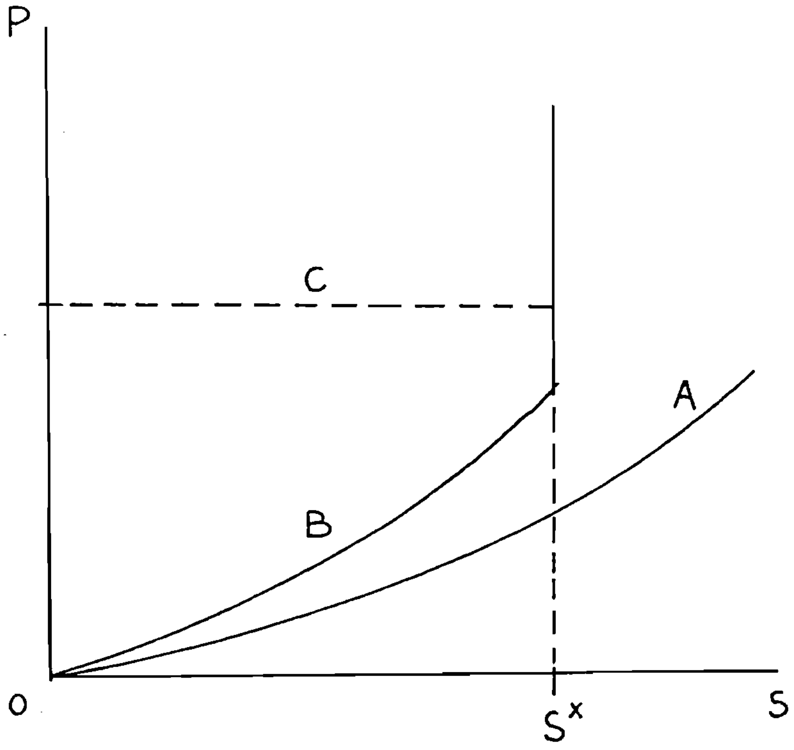

Figure 3. The forest products trade model uses export equations that are either (A) price-elastic for any quantity exported, (B) price-elastic up to a maximum supply S^X, (C) infinitely price elastic up to a maximum supply.

DYNAMIC RELATIONSHIP BETWEEN EQUILIBRIA

The purpose of this section is to describe how the equilibrium solution in any given year is related to the solution(s) in the previous year(s). As illustrated in Figures 1 and 2, the solution in any year is determined primarily by the position in the price-quantity plane of the demand functions for imports and the supply functions for exports of all countries. Between periods, the positions of the demand and supply functions way shift. To illustrate how these shifts are calculated, consider the case of a demand function (Figure 4).

Let D_0, P_0 be the equilibrium quantity and CIF price of a commodity imported by a country in a specific year. This may be either the initial condition or the result of an optimization described in the previous section. Then, were price to remain the same, the quantity imported the next year, D_1^0, would be

$$D_1^0 = D_0 + \Delta D_0 \qquad (6)$$

where

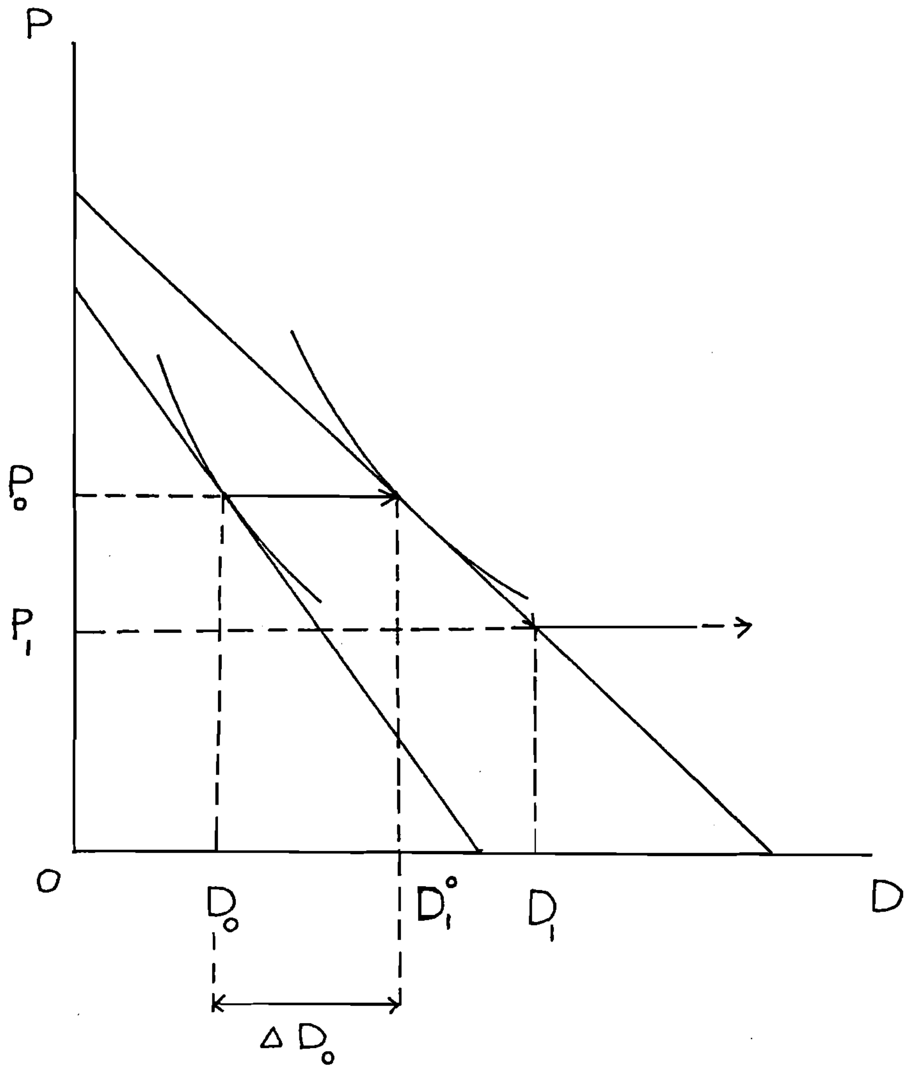

Figure 4. The current trade equilibrium (P_1, D_1) is computed from the one in the previous year (P_0, D_0) by a shift of the demand schedule (ΔD_0) followed by a movement along a linear approximations of that schedule.

$$\Delta D_0 = D_0 \left(\sum_{m=1}^{M} \omega_m \frac{\Delta Y_m}{Y_m} + \omega_0 \right) \tag{7}$$

in which Y_m is a specific shifter of the demand for imports, of which there are M, and ω_m is the elasticity of the demand for imports with respect to Y_m. Expressions (6) and (7) assume therefore that the demand for imports can be represented in the vicinity of the equilibrium (P_0, D_0) by a generalized Cobb-Douglas Function of the form:

$$D = e^{\omega_0 t} \prod_{m=1}^{M} Y_m^{\omega_m} P^{\rho} \tag{8}$$

But, because (8) is used in its differential form in (7), one needs to know only the initial conditions (P_0, D_0), the elasticities ω_m and the rates of change of the shifters $\frac{\Delta Y_m}{Y_m}$.

Having the point P_0, D_1^0, one then determines using equation (4) the slope of a linear approximation to the demand equation going through that point and of elasticity ρ with respect to price. Finally, the new equilibrium point (P_1, D_1) on that demand curve is calculated using the optimization procedure described in the previous section. These two steps, shifting the demand curves followed by movements along the curves to a new equilibrium, are repeated for each year of a forecast.

Shifts of the supply schedule for exports of a particular commodity originating from a specific country are handled exactly as shifts of a demand schedule for imports. When there is an upper bound on exports, S^X that upper bound is shifted along with the rest of the supply schedule.

The shifters in equation (7) may refer to either exogenous or lagged endogenous variables. For example, Y_1 can be gross national product in the country of interest (an exogenous variable), Y_2 the quantity of that commodity imported last year, and Y_3 the CIF price of these imports (both lagged endogenous variables), Y_4 can be the price last year of another imported commodity, thus allowing for cross-price elasticities. In principle, the entire array of equilibrium prices and quantities in all previous years can be used to calculate shifts of the demand or supply functions in the current year. But practical considerations and available knowledge limit the actual number of shifters. Other methods of generating intra-period shifts are possible and, in fact, may be desirable. Conceptually, revised or updated demand and supply functions could be taken directly from a more detailed model of a region. Because we do not have access to such models, we have chosen to demonstrate the linkage system using a small set of shifters.

BARRIERS TO TRADE AND INERTIA

The discussion so far has dealt with a model of international trade for forest products in which market forces alone operate. Nevertheless, trade barriers and agreements of various kinds, including tariffs, taxes, and quotas limit the role of pure market forces. In addition, the full adjustment of trade relationships to market forces may take much more than one year, due to the cost of changing current trade arrangements, lack of information and similar factors.

Consider first the case of quotas. Let Q_{jk}^X be the maximum amount of commodity k a set of countries E_{jk} is allowed to export to country j, in any given year. This quota can be represented by the following constraint:

$$\sum_{i \in E_{jk}} T_{ijk} \leq Q_{jk}^X \qquad j \in IQ_k,\ k \in IC \tag{9}$$

A constraint of this type is needed for each country with an import quota on commodity k.

Inertia in adjustment of trade flows can be represented by the following inequalities

$$(1-\alpha_{ij})T_{ijk}(t-1) \leq T_{ijk}(t) \leq (1+\alpha_{ij})T_{ijk}(t-1) \qquad i \in I_{jk},\ j \in J_{ik} \tag{10}$$

where $t-1$ and t refer to the year during which the trade flow is observed. The coefficient $0 \leq \alpha_{ij} \leq 1$ measures the speed of adjustment. If it is zero there is no adjustment of trade flows to new economic conditions. Trade flows between two specific countries are the same as they were the year before, reflecting infinite inertia. As the value of α_{ij} increases the possible difference between the current trade flow and the one observed last year increases.

Another, complementary approach to model market inertia is to use the demand and supply functions. Consider, for example, the demand for imports (8). Assume that two shifters are used, one being last-year imports (D_{-1}) and the other gross national product (G), so that D has the expression:

$$D = \alpha D_{-1}^{\beta} G^{\gamma} P^{\rho} \tag{8)'$$

Here, a high value of β would reflect strong inertia while $\beta=0$ would correspond to no inertia at all.

Then, equation (7) becomes

$$\Delta D_0 = D_0\left(\beta \frac{\Delta D_{-1}}{D_{-2}} + \gamma \frac{\Delta G}{G}\right) \tag{7)'$$

where $\Delta D_{-1} = D_{-1} - D_{-2}$, available from previous equilibrium solutions.

Tariffs take usually the form of fixed ad-valorem taxes on the value of the commodity imported. The effect of a change in the tariff rate is exactly the same as that of a change in price and is thus measured by the elasticity ρ. A tariff can therefore be included as a shifter in equation (7) with an elasticity ρ. Note that what matters to predict changes in trade are changes of the tariff rate, not the level of the tariff.

COMPUTER SOFTWARE

The principles presented in the previous sections were applied using a system of six computer programs developed previously (Gilless and Buongiorno 1982). As shown in Figure 5, programs DEMAND and SUPPLY generate the import and export schedules from basic data on the quantities imported and exported by each country during the base year of a projection, and from the price elasticities of imports and exports, respectively. The output of these two programs are the linearized forms of the area under the import and export schedules. These data, together with information on trade barriers (equations 9) and trade inertia (equations 10 and 8') are used by program MATRIX to build the linear programming matrix describing the trade equilibrium in the base year.[1]

This problem is solved by the program FMPS, a SPERRY-UNIVAC program for solving large mathematical programming problems. The solution produced by FMPS is printed by program REPORT which also calculates equilibrium CIF and FOB prices based on quantities imported and exported and corresponding import and export functions. The equilibrium solution obtained is used by program UPDATE, together with basic data provided by the user, to prepare a new linear programming matrix. This matrix expresses the new equilibrium problem after all shifts of the import and export schedules during one year have been simulated. The new equilibrium problem is then solved by program FMPS. The iterations among FMPS, REPORT and UPDATE continue until the last year of the projection period.

APPLICATION TO NEWSPRINT TRADE

The concepts and software described above have been applied to a prototype model of the international trade of newsprint. In 1980 total world imports of newsprint were estimated at 12.7 million metric tons, valued at some 5.8 billion dollars (FAO 1983:317-319). Table 2 shows the distribution of this trade by major exporting and importing countries or regions. This division was selected to maintain the main trade flows while keeping the number of countries reasonably small in this first model. Restricting the analysis to newsprint assumes also that newsprint trade is independent of trade of other products. As indicated earlier, the model structure does not require that assumption, it is used here for simplicity and can be lifted later.

1) With the current software, trade constraints for quotas and inertia must be added manually to the matrix.

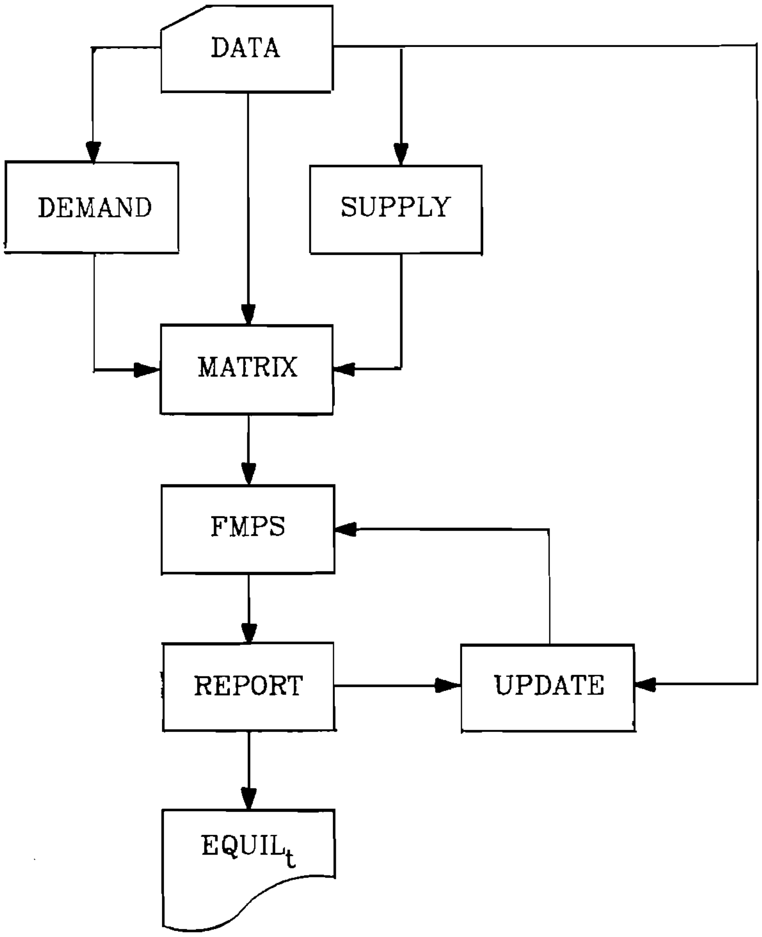

Figure 5. The software of the trade model uses six programs. DEMAND, SUPPLY, and MATRIX are used to specify the equilibrium problem for the base year. FMPS, REPORT, and UPDATE solve and update the equilibrium problem for each year in the projection period.

Initialization of the model requires data on quantities imported and exported by each individual country and corresponding CIF and FOB prices (Tables 3 and 4), together with price elasticities of imports and exports (Tables 5 and 6). It also requires estimates of transportation costs along major trade routes (Table 7). Transportation costs from various suppliers to ROWI (rest of the world importers) are difficult to define and are therefore not used in the model. Instead, it is assumed that exporters in Canada, Nordic, and ROWE (rest of the world exporters) are facing a demand for imports from the rest of the world, but with no intermediate transport costs. The price elasticity of that demand is equal to that of ROWI in Table 6. The initial point on the demand curve is defined by the quantities exported by Canada, Nordic, and ROWE to ROWI, and by the corresponding FOB prices (Table 4). Imports by ROWI are handled in in the same manner.

Table 2. Regional Classification and 1980 trade flows. (Source: FAO 1983:369).

Exporter / Importer	Canada	Nordic	ROWE[1]	Total[2]
		----- 1000 mt -----		
USA	6,209	64	321	6,594
W. Europe	582	2,117	237	2,936
Japan	16	0[3]	111	127
ROWI[5]	900	1,012	1,152	3,064
Total	7,077[4]	3,193[4]	1,821	12,721

1) Rest of the world exporters, calculated as the difference between the figures in the Total column and the figures in the Canada and Nordic columns
2) Total imports reported by importers
3) Included w/ ROW to Japan (2000 mt)
4) Total exports reported by exporters
5) Rest of the world importers, calculated as the difference between the figures in the Total row and the figures in the USA, W. Europe and Japan rows

The above information is sufficient to calculate the trade pattern consistent with market equilibrium assuming pure competition and no trade inertia. There does not seem to be barriers to trade for newsprint either in the form of tariffs or quotas. On the other hand, adjustments of trade to new market prices may well take more than one year. For that reason, it was assumed that the volume of newsprint traded between two countries could not differ by more than 25% with respect to the volume traded in the previous year.[2)]

Forecasts of newsprint trade were made for the period 1980-1985. It was assumed that equations of demand for imports and supply of exports would continue to shift at the same rate as they had between 1970 and 1980. The corresponding rates of shift are reported in Table 8. The very high rate of shift for Japan was reduced to zero beyond 1982. The unit transport costs estimated for 1980 (Table 7) were maintained throughout, thus assuming that transport costs would remain constant in real terms between 1980 and 1985.

2) Due to poor data on the trade of Japan with the rest of the world, a broad range between 40,000 mt and 400,000 mt was specified for the base year.

Table 3. Newsprint exports in 1980 by country or region. (Source: FAO 1983:369).

Country or region	Quantity (10^3 mt)	Price
		FOB ($/mt)
Canada	7,707	408
Nordic[1]	3,193	469
ROWE		CIF ($/mt)
To USA	321	400
To W. Europe	237	580
To Japan	111	547
To ROWI	1,152	456

1) Sweden, Finland, Norway

Table 4. Newsprint imports in 1980 by country or region. (Source: FAO 1983:369).

Country or region	Quantity (10^3 mt)	Price
		CIF, ($/mt)
USA	6,594	400
W. Europe[1]	2,936	580
Japan	127	547
ROWI[2]		FOB ($/mt)
From Canada	900	408
From Nordic	1,012	469
From ROWE	1,152[1]	430

1) UK, Germany FR, France, Netherlands, Denmark, Belgium, Luxembourg

2) Rest of the world importers, data from Table 1.

Table 5. Elasticity of newsprint exports with respect to the FOB price of newsprint. (Source: Hassan and Wisdom 1983)

Country or region	Elasticity
Canada	2.1
Nordic	0.6
ROWE	0.58

Table 6. Elasticity of newsprint imports with respect to the price of newsprint. (Source: Hassan and Wisdom 1983)

Country or region	Elasticity
USA	-0.38
W. Europe	-0.29
Japan	-0.27
ROWI	-0.31

Table 7. Cost of shipping newsprint along major trade routes in 1980 ($/mt).

From To	Vancouver	Montreal	Stockholm
New York	X	29	90
Rotterdam	X	69	22
Yokohama	84	X	X
ROWI	X	X	X

X: Shipping routes not used in model.
Estimated from FR = -0.9 + 0.02 DI where FR is shipping cost in $/mt and DI is distance in nautical miles (Hassan and Wisdom 1982). DI estimated from Defense Mapping Agency (1971).

Table 8. Estimation of the shifts of import demand and export supply functions, 1970-1980.

Region	Annual quantity change	Annual price change	Elasticity	Annual rate shift
		Exports		
Canada	0.008	0.112	2.10	-0.0403
Nordic	0.040	0.114	0.59	0.075
World	0.020	0.124	0.58	-0.0003
		Imports		
USA	0.014	0.103	-0.38	0.019
W. Europe	0.092	0.152	-0.29	0.110
Japan	0.145	0.160	-0.27	0.164
World	0.020	0.124	-0.31	0.031

Note: The annual rate of shift, α, of the export function for a particular country is calculated as $\alpha = \frac{\Delta S}{S} - \tau(\frac{\Delta P}{P} - \frac{\Delta W}{W})$ where τ is the price elasticity of exports, $\frac{\Delta S}{S}$ is the annual rate of change of exports during 1970-1980, $\frac{\Delta P}{P}$ the rate of change of the FOB price in US dollars, $\frac{\Delta W}{W}$ the rate of change of all producer prices in the United States (estimated at 0.089 per year during the period of interest (Ulrich 1981:5)). The same approach is used for imports.

The forecasts are summarized in Tables 9 to 12. The ex-post forecasts for 1980 are of special interest because they give an indication of the ability of the model to predict prices and quantities, given correct assumptions regarding exogenous shifters. As shown in Table 9, predicted exports for the year 1980 are within 5 percent of actual exports and FOB prices within 1 percent of actual prices. For the same year, predicted imports were within 4 percent of actual values and CIF prices within 14 percent. The largest errors occurred for the United States (a 10 percent over estimation of the price) and Western Europe where it was underestimated by 14 percent. Table 11 compares the predicted and actual trade flows in 1980. Relative errors were generally inversely related to the magnitude of trade flows. The largest trade flow, from Canada to the USA was underestimated by 5 percent, the smallest, from Canada to Japan was overestimated by 25 percent. Somewhat disappointing is the fact that the important trade flow from Canada to Western Europe was overestimated by 22 percent.

From these first result is seems appropriate to conclude that although the model can predict total imports and exports with adequate accuracy, given appropriate assumptions regarding exogenous shifters, it does not predict each individual trade flow accurately. This does not seem critical however for the purpose that the model is to serve, namely that of a linkage procedure insuring that forecasts of total imports or exports of a country and corresponding prices are consistent with those of other countries.

According to the results, the total volume of newsprint exported (imported) would increase by some 10 percent between 1980 and 1985. The average world price would rise by some 19 percent over the same time period. The main source of supply would be Canada where exports are predicted to grow by 22 percent, compared to some 14 percent for Nordic countries over the projected period (Table 9). There would be little growth of imports by the United States. The main demand pull would occur in Western Europe where imports would rise by 61 percent during the forecast period (Table 12). This can be traced back to the annual rate of shift of 11 percent assumed for the demand for imports in Western Europe (Table 9). It is very unlikely that this rate will be sustained. This points to the necessity to understand the forces behind the movement of the demand for imports, i.e., the need to decompose the rate of shift into various components as outlined above. One could then predict readily the effect of various assumptions regarding the rate of change of various shifters.

Table 9. Newsprint export quantity and price forecasts 1980-1985.

Country	1980	1981	1982	1983	1984	1985
			----- Quantity (1000 mt) -----			
Canada	7,553 (-0.02)[1]	7,871	8,013	8,304	8,766	9,200
Nordic	3,202 (+0.00)	3,355	3,443	3,537	3,635	3,662
ROWE	1,908 (+0.05)	1,852	1,888	1,918	1,953	1,972
			----- Price ($/mt, FOB) -----			
Canada	404 (-0.01)	420	432	449	470	491
Nordic	471 (+0.00)	503	519	536	553	553
ROWE	460 (+0.01)	478	496	508	523	536

1) Relative deviations from observed quantities.

Table 10. Newsprint import quantity and price forecasts 1980-1985.

Country	1980	1981	1982	1983	1984	1985
			----- Quantity (1000 mt) -----			
USA	6,340 (-0.04)[1]	6,460	6,331	6,332	6,404	6,396
W. Europe	3,053 (+0.04)	3,379	3,675	4,052	4,498	4,919
Japan	129 (+0.02)	144	160	162	166	166
ROWI	3,040 (-0.01)	3,095	3,178	3,223	3,286	3,354
			----- Price ($/mt, FOB) -----			
USA	441 (+0.10)	441	465	488	496	521
W. Europe	500 (+0.14)	505	540	553	552	580
Japan	519 (+0.06)	595	706	675	595	595
ROWI	447 (+0.04)	464	472	461	512	527

1) Relative deviations from observed quantities.

Table 11. Predicted and observed trade flows of newsprint in 1980.

Exporter Importer	Canada	Nordic	ROWE	Total
		----- 1000 mt -----		
USA	5,924 (-0.05)[1]	82 (+0.43)	334 (+0.04)	6,340 (-0.04)
W. Europe	709 (+0.22)	2,108 (-0.01)	236 (-0.00)	3,053 (+0.04)
Japan	20 (+0.25)	- (-)	109 (+0.02)	129 (+0.02)
ROWI	900 (0.00)	1,011 (0.00)	1,129 (-0.02)	3,040 (-0.01)
Total	7,553 (-0.02)	3,201 (0.00)	1,808 (0.01)	12,562 (-0.01)

1) Relative deviations from observed quantities.

Table 12. Predicted trade flows of newsprint - 1985.

Exporter Importer	Canada	Nordic	ROWE	Total
		---- (1000 mt) ----		
USA	6,001	19	375	6,395
W. Europe	2,162	2,534	223	4,919
Japan	51	-	115	166
ROWI	986	1,109	1,259	3,354
Total	9,200	3,662	1,972	14,834

SUMMARY AND CONCLUSIONS

The purpose of this paper was to give an example of how different models of the forestry sector of many countries can be linked. The linkage is necessary to insure that forecasts of imports and exports, and corresponding prices, of one country are consistent with those of its trading partners. Consequently, resolution of the linkage problem consists in developing an adequate model of international trade for forestry products.

The premise of the method used here is that the output of each individual country model can be reduced to a small number of simple parameters, variables and relationships that are sufficient to predict exchanges between countries. It is suggested that the output of the country models must be simplified in that manner to make the linkage at all possible. There are several reasons for this. First, the methodology used by teams in different countries may be quite different. For example, existing country models use econometrics, systems dynamics and mathematical programming, often in different combinations. This diversity is appropriate given the different conditions and the expertise of modelers in each country. In fact, variety of modeling approaches is a good way to discover the advantages and inconveniences of each.

Another reason to simplify and standardize the output of each country model is computational. It is unlikely that, given the resources of this particular project and the time limits, a global linkage could be developed that solves simultaneously the individual country models, at least in their original detail.

A third reason for keeping the linkage mechanism simple is that only a few countries will have the resources to develop detailed forestry sector models during the period of this project. For the other countries it is important to state early what minimum information they must provide to be considered explicitly in the trade model. It must also be kept in mind that many countries do not participate in the forestry sector project. The role of these countries (or regions) in forest products trade must be taken into account and, given the resources available, this must be done as simply as possible.

For these reasons the paper suggests that the link between the forestry sector of a country and the rest of the world consist of simple functions describing the demand for imports or/and the supply of exports for each commodity of interest. These functions are defined by initial conditions and elasticities with respect to price and as many shifters as necessary. Shifters include strictly exogenous variables or lagged endogenous variables.

Given functions describing the demand for imports and supply of exports of each country the projection of world trade and corresponding prices proceeds in the following manner. Equilibrium prices and quantities in any given year are determined by assuming a competitive world market for forest products. This is done by an algorithm that maximizes the surplus value of world trade in that year. Constraints are used to account for trade barriers that limit competition, or inertia that limits the movement towards equilibrium within a year.

After the equilibrium trade for a specific year has been computed all export supply and import demand functions are shifted for a one-year period. The shifts are calculated using the expected rates of change of exogenous variables, or the computed rates of change of lagged endogenous variables and the corresponding elasticities. A new equilibrium solution is then calculated and the procedure is repeated for the entire forecast.

This methodology has been applied in this paper to the trade of newsprint between Canada, Japan, Nordic countries, Western Europe, the USA and the rest of the world, for the period 1980 to 1985. For this prototype model, rough estimates of price elasticities of imports and exports were used based on published data. The forecasts for 1980 compared reasonably well with observed data. All calculations were done using software developed previously (Gilless and Buongiorno 1982). Only slight modifications were needed. Trade inertia constraints that were added manually could be programmed into the software.

Undoubtedly, adaptation of existing software would save time that could be devoted to the improvement of data and to the analysis of alternative forecasts. Lack of data is by far the main obstacle for the development of a complete model of international forest products trade. Even the simple framework used here requires a considerable amount of information that is not available readily. To start with, price elasticities of imports and exports for different countries and products must be determined. Also needed are the variables that cause import and export functions to shift over time, their corresponding elasticities, and some estimate of the rate of change of these variables. For the international linkage between national sector models to be possible, the later models must be designed to provide these data. This minimum information can be obtained from a variety of models. For example, assume Finland has a mathematical programming model of its forestry sector. One of the parameters in that model would probably be the FOB price of pulp exports from Finland. Using such a model, it should be possible to determine readily the sensitivity of pulp exports to changes in the FOB price, i.e., the price elasticity required to link Finland to the rest of the world using the methodology proposed here. Obviously, other approaches are needed in countries that do not have a detailed sector model. In some countries, elasticities may be available from previous studies or new econometric estimates may be calculated. In the worst case, educated guesses will have to be used, keeping in mind that they can be changed when the trade model is calibrated.

With these considerations in mind, it is recommended that if the methodology outlined in this paper, or some variant is adopted, the individual country teams be contacted to determine whether they can provide the kind of information required. A checklist for this purpose appears in Table 13.

Table 13. Information required from individual countries for each commodity traded by that country.

1.	Quantity imported (exported) in base year, measured in m^3 or m.t.
2.	CIF price of imports and/or FOB price of exports in base year, in US$ per m^3 or m.t.
3.	Elasticities of imports (exports) with respect to CIF (FOB) price.[1]
4.	Exogenous shifters of import (export) functions, e.g., population, gross national product.[2]
5.	Lagged endogenous shifters of import (export) functions, e.g., past CIF price, past exports.[3]
6.	Elasticities of imports (exports) with respect to shifters.
7.	Expected rates of change of exogenous shifters during projection period.
8.	Quantities imported from (exported to) other countries in model during the year, and maximum possible yearly variation (percent).
9.	Transport costs for shipments of exports and import along relevant routes in base year ($/$m^3$ or m.t.)
10.	Expected rates of change of transport costs.
11.	Quotas on quantities imported (m^3. m.t.), and tariff rates.
12.	Expected rates of change of quotas and tariffs.
13.	Upper bounds on quantities exported.
14.	Expected rates of change of upper bounds on exports,

1. Express relative change in imports (exports) for a unit relative change in constant dollars.
2. Only definitions of shifter variables are needed, not data on their value.
3. Lagged endogenous shifters refer to past prices and quantities traded for any country and commodity considered in the model.

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