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Modelling International Trade in Forest Products (Preliminary Ideas)

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MODELLING INTERNATIONAL TRADE IN FOREST PRODUCTS (PRELIMINARY IDEAS)

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ABSTRACT

The author was asked by the forest modelling group to present his ideas on how international trade of forest products should be modelled. It should be stressed that the ideas presented here are very preliminary ones without any detailed knowledge of the specific features of forest products.

It is suggested that the preparation of the international linkage of national forest product models should start with an analysis of the historical pattern of trade. Two methods are presented: the gravitational analysis to understand better the factors influencing trade flows and the trade intensity analysis to study the bilateral pattern of trade and their evolution in time.

In the second part of the paper the linkage of national models through trade flow matrices is discussed and it is suggested that information on trade intensity changes should be used also in the linkage process and estimated inconsistencies of the world market should influence the policy part of the national models.

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MODELLING INTERNATIONAL TRADE IN FOREST PRODUCTS

(Preliminary Ideas)

This note consists of two parts: in the first, suggestions are made on how best to study the structure and dynamic change of international trade in forest products, and in the second some ideas are presented on the linkage of aggregated national (regional) forest sector models.

I. Analysis of international trade in forest products

To understand the behaviour, structure and dynamic change of the international market for forest products, data have to be assembled on the trade flows of these products. In the trade flow tables (where rows represent the allocation of exports among countries and columns the origin of imports) the entries represent both exports and imports, i.e. the exports from country i to country j are equal to the imports to country j from country i (see Figure 1).

These tables should be calculated for various product groups depending on the availability of and the level of disaggregation used in our model linkage exercise. These tables can be treated as three-dimensional matrices (see Figure 2) for each year and a time series of these matrices should be assembled for as many years as possible.

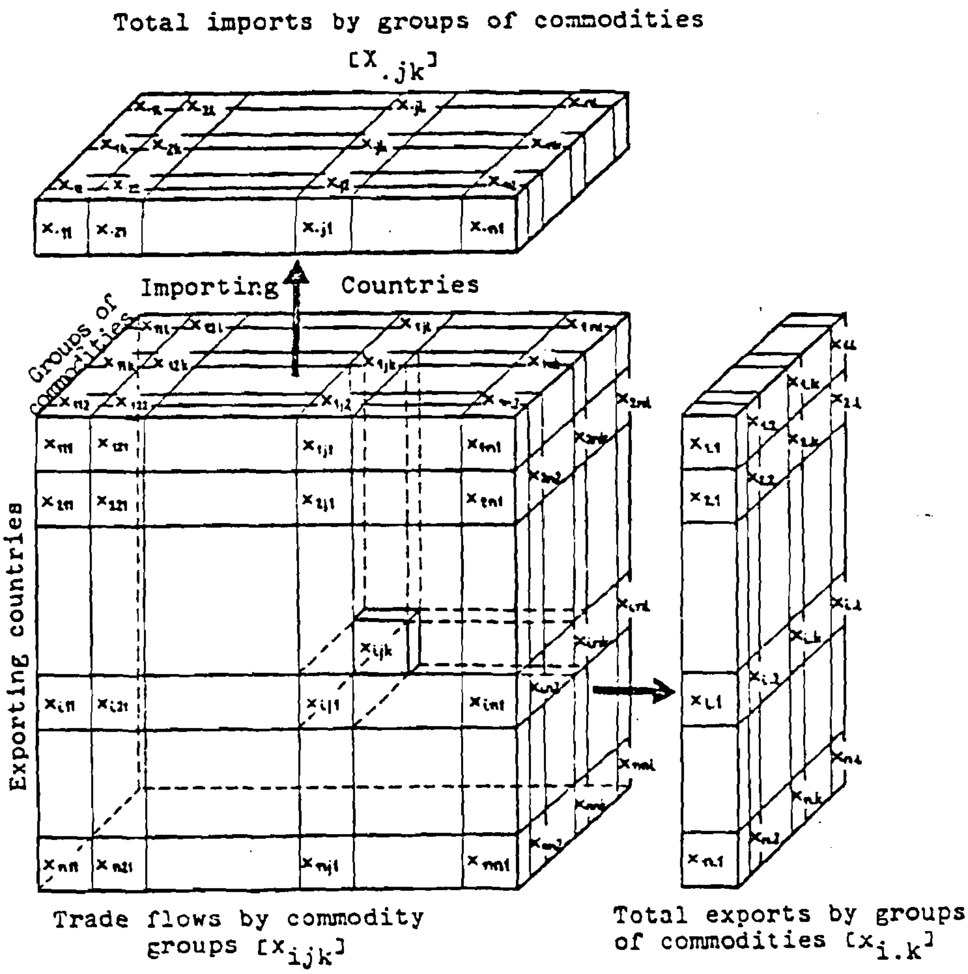
If X_{ijk} is the amount of commodity k exported by country i to country j and aggregation over a particular index is indicated by replacing the index by a dot (·), then $X_{i.k}$ is the total exports of product k by country i, $X_{.jk}$ is the total imports of the same product by country j, and $X_{..k}$ is the total world trade in product k. Total trade is naturally equal to both the sum of total exports and the sum of total imports:

$$X_{..k} = \sum_i \sum_j X_{ijk} = \sum_i X_{i.k} = \sum_j X_{.jk}$$

Fig. 1. Table of total trade flows among countries

Exporting countries	Importing countries						Total exports
	1	2	...	j	...	n	
1	$X_{11.}$	$X_{12.}$		$X_{1j.}$		$X_{1n.}$	$X_{1..}$
2	$X_{21.}$	$X_{22.}$		$X_{2j.}$		$X_{2n.}$	$X_{2..}$
⋮							
i	$X_{i1.}$	$X_{i2.}$		$X_{ij.}$		$X_{in.}$	$X_{i..}$
⋮							
n	$X_{n1.}$	$X_{n2.}$		$X_{nj.}$		$X_{nn.}$	$X_{n..}$
Total imports	$X_{.1.}$	$X_{.2.}$		$X_{.j.}$		$X_{.n.}$	$X_{...}$

Figure 2. The three-dimensional matrix of trade flows



Once these matrices have been calculated, various methods can be used to analyse how the market shares of the different exporters and importers change in time, how the trade balances are changing, etc.

1) *Gravitational analysis*

A gravitation model[1] can be used to obtain a better understanding of the factors influencing trade flows. It is assumed that trade flows between two countries are functions of their trading capacities and the "resistence" hindering or "attractions" strengthening trade between the given pair of countries.

Trading capacities can be represented by the potential supply of the exporting and potential demand of the importing country. Potential export supply is that part of production which exceeds domestic demand, and therefore depends on the production of the given country and on the ratio between production for home and foreign markets. It can be assumed that these ratios depend on the capacity of the domestic market to absorb the product. The larger a country's domestic market, the greater the number of branches of manufacturing industry that will exceed the limit of efficient production and consequently the higher will be the share of ouput satisfying domestic demand.

In the gravitation models of aggregated trade flows the potential supply and demand is generally expressed by the GDP of the exporting and importing countries and by their population sizes, representing their domestic absorbing capacities. In the case of forest products, potential supply and demand could be expressed more directly by the total output of the exporter and the total demand of the importing country, and the domestic absorbing capacity of the exporting country could be represented by the domestic input of the given commodity. As the market size of the importing country is already expressed by its total input, there is probably no need for another variable in this case.

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[1] See: Linnemann [1966], Nagy [1979], Pulliainen [1963], Tinbergen [1962].

The "resistance" factors, or barriers to trade, are of two types: a) natural, like distance and b) artificial, like tariffs, quantitative restrictions, etc. These factors are difficult to quantify, although this is slightly easier for the former than the latter. One method of quantification in the first case would be to use physical distances, measured in kilometers, but it would of course be better to use some economic distance measure, distinguishing, for instance, between sea and land transportation costs. In the case of very large countries, it is difficult to define the points of where goods arrive and depart and therefore to measure the distance. It is even more difficult to quantify the artificial trade impediments, although several methods for doing so are suggested in the literature. The forest products industry, however, has the advantage that these barriers are less important (at least in the primary phases of production) than in more sophisticated manufacturing.

The "attraction" factor is at work when political or economic alliances create zones of preference and the trade flows between members of the same preference area are proportionally greater than might have been expected without these effects. Such preference areas may have former colonial links (like the British Commonwealth), they may be areas of economic cooperation (like the EEC, or the CMEA), or they may be bound by close ties such as those which link Canada or the Latin American countries to the U.S. In the case of forest products, such preference relations may exist as a consequence of long-term agreements also.

Having chosen all these explanatory variables, a gravitational model can be constructed in the following way:

$$X_{ijk} = c\,\frac{S_{ik}^{a_i}\,D_{jk}^{a_2}\,P_{ijk}^{a_5}}{d_{ij}^{a_3}\,t_{ijk}^{a_4}\,M_{ik}^{a_6}}$$

where: S_{ik} = amount of commodity k produced by country i

D_{jk} = amount of commodity k required by country j

d_{ij} = distance from country i to country j

t_{ijk} = tariff (and other trade barriers) imposed by by country j on commodity k imported from country i

M_{ik} = amount of commodity k required by country i

P_{ijk} = preference dummy variable for trade in commodity k between countries i and j.

$a_i,\ldots,a_6$ = parameters of the explanatory variables

Some of the variables express more general effects, like the export "push" (S and M), the import "pull" (D), while others represent special relationships influencing bilateral trade relations (d,t,P). We can assume that some of the variables have a positive effect on trade flows (S,D,P), while the influence of others is negative (d,t,M).

The parameters of the gravitational equation above can be estimated by regression analysis. There is a high probability that significant relationships can be revealed between the trade flows as dependent variables and the explanatory variables already described. It is possible to estimate the correlation between variables for all trade flows for a given commodity or for only certain sets of them (e.g. by periods, or by exporting countries). Certain explanatory variables can be changed during the computations (inclusion of population representing market size, expressions of economic distance, different quantifications of trade impediments) to see how the fit changes, or whether it can be improved.

Gravitational analysis reveals generally valid interrelations between trade flows and the factors influencing them, but it cannot be expected to explain or forecast individual trade flows with an acceptable level of accuracy. The relative error of "expected" flows compared with actual flows in previous similar calculations has been found to be about 30-40%. An analysis of the differences between calculated and actual flows can nevertheless be highly instructive, because it may show how the individual divergences of the dependent variables are distributed.

By comparing the estimated parameters of the different explanatory variables, it is possible to draw conclusions about the relative "strength" of export "push" and import "pull" in forest products trade. All previous studies of this type showed that the "push" of the exporter had a stronger influence on trade flows than the "pull" of the importer.[2] Similarly, the effects of obstacles to trade and of trade preferences can be measured and their changes over time can be observed.

The major weakness of gravitational analysis is that the special factors influencing bilateral flows are very inadquately represented by the variables d, t and P. This is the main reason why the multiple correlation coefficient is usually not very high and the relative error of ex post analysis is great; in other words, a considerable part of the deviations of the dependent variables remain "unexplained".

2) *Trade intensity analysis*

If we are interested in the detailed structure of international trade in general, or of trade in a particular group of products, gravitational analysis will not satisfy us, because we are more concerned with the pattern and behaviour of bilateral trade relations than with the "average" effects of certain exogenous variables on trade flows. This is the case when we wish to look into the future, making projections, comparing conditional scenarios, or linking national projection models.

2/ A comparison of different gravitational computations is presented in Nagy, op. cit., p. 53.

Several methods can be used in the systematic analysis of trade flow structures: the most common is to use share structures to describe various aspects of the system. For example, global models frequently include import share matrices which describe the distribution of imported goods according to their country of origin. If national models produce import vectors, then these can be multiplied by the import share matrices to give trade flows, which, when summed for each exporter, give the total exports of each country.

However, share structures tell us nothing about why these shares are as they are, or why they are changing. To go one step further, it is necessary to study bilateral trade intensities which are designed to separate and quantify some of the factors determing trade flow structures. The concept of trade intensities[3] is closely related to gravitational analysis in that trade flows depend on the "push" of the exporting country, the "pull" of the importing country and on particular factors regulating bilateral relations.

This classification of factors into two categories leads to a method which treats the "volume effects" (the trade potential of the two countries) and the "intensity effects" separately. This is done by firstly computing a hypothetical "normal" flow, taking into account only the volume effects, and then comparing this with the actual flow data, thus obtaining the intensity effect as a residual. For the sake of simplicity, we shall introduce exporter's and importer's trade flow shares in the trade in a particular group of commodities:

$$z_{ijk} = \frac{X_{ijk}}{X_{..k}} ,$$

and we can obtain "normal" flow shares (denoted by an overbar) by multiplying the exporter's share in total exports by the importer's share in total imports:

$$\bar{z}_{ijk} = z_{i.k} \; z_{.jk}$$

[3] See: Froment and Zighera [1964], Marin-Curtoud [1965], Nagy [1969], ECE [1973], Theil [1967].

It must be realised that the idea of "normal" trade flow is an abstraction. Actual bilateral flows would be "normal" only if exporters distributed their exports according to the size of the import markets and importers bought goods according to the shares of the exporters in the overall trade in the given commodity.

The intensity of bilateral trade relations is taken to be the factor causing observed bilateral flows to deviate from "normal" behaviour.

$$\delta_{ijk} = \frac{z_{ijk}}{\bar{z}_{ijk}} = \frac{z_{ijk}}{z_{i.k}z_{.jk}}$$

and therefore the trade intentsity coefficients reflect all factors affecting trade flows apart from the "volume effects", including distance, trade policy measures, discrimination, integration, historical links, etc. If these factors have little effect on bilateral trade, the value of δ will be one, or thereabouts, while if they increase or reduce the trade flow, the coefficient will be greater or less than unity, respectively.

As the transportation costs of forest products play a significant role in influencing trade flows, the trade intensity coefficient can be divided into two factors, one expressing economic distance (α) and the other (β) representing the effects of trade policy:

$$\delta_{ijk} = \alpha_{ijk} \cdot \beta_{ijk} \quad .$$

The distance coefficient α can be quantified with the help of gravitation analysis, taking into account the distance between exporting and importing ports and the type of transportation used. If this is done then the coefficient β will express all trade policy factors affecting bilateral flow and can be obtained as a residual by comparing actual trade flow shares with normal flow shares multiplied by the distance coefficient α:

$$\beta_{ijk} = \frac{Z_{ijk}}{\bar{Z}_{ijk}\alpha_{ijk}} = \frac{Z_{ijk}}{Z_{i.k}Z_{.jk}\alpha_{ijk}}$$

The trade policy coefficient is a highly general index which summarises the effects of the very diverse factors influencing trade between pairs of countries. However, it seems likely that this coefficient will show some stability or regularity of change for trade in forest products as has been found for trade in other products in previous studies.

One important feature of the trade intensity coefficient (δ) matrices is that their row and column totals weighted by the total export- and import-shares equal unity[4]:

$$\delta_{ijk}Z_{.jk} = \frac{Z_{ijk}}{Z_{i.k}}, \text{ consequently: } \sum_j \delta_{ijk}Z_{.jk} = 1 \text{ and}$$

$$\delta_{ijk}Z_{i.k} = \frac{Z_{ijk}}{Z_{.jk}}, \text{ consequently: } \sum_i \delta_{ijk}Z_{i.k} = 1.$$

It therefore follows that if we take the inverse of the matrix of δ coefficients (Δ_k), and sum the rows and the columns, we obtain the total export and import shares:

$$Z_{.jk} = \Delta_k^{-1}.\underline{\underline{1}} \text{ and } Z_{i.k} = \underline{\underline{1}}.\Delta_k^{-1}$$

The structures determined by the δ and the Z coefficients both have one degree of freedom. A given δ coefficient system determines the total export- and import share vectors, and the close interrelation of the δ_{ijk} coefficients with the $Z_{i.k}$, $Z_{.jk}$ share vectors is very useful when trying to produce consistent projections or scenarios.

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[4] This is only true when no zeroes occur in the diagonal of the matrix, as, for example, when we have regions instead of countries. There are several technical means of overcoming this problem, see: Marin-Curtoud, op. cit.

Both intuition and observation of the past behaviour of the intensity coefficients suggest that they undergo certain distinct types of change, four of which are discussed below.5/

(a) "normalisation" of international trade relations, meaning liberalization of trade, which reduces the deviation of real from so-called "normal" flows; this is reflected in δ coefficients by a closer approach to unity from either above or below;

(b) integration of certain groups of countries, increasing the intensity coefficients for intra-regional trade to values above unity and decreasing those for extra-regional trade to values below unity;

(c) "flattening out" of the trend, meaning that the rate of change diminishes as the intensity coefficient approaches a certain level (unity, in case (a), or a higher or lower level (in case (b));

(d) in a situation in which the direction of movement of the intensity coefficient is opposite to the trends described in a and b, the trend must finally revert to (a) or (b) over time.

Observation of the past behaviour of bilateral trade intensities can be of great help in projecting them for the future, even if it cannot be generally assumed either that they will remain unchanged, or that the direction and rate of change will follow past trends.

II. LINKING NATIONAL FOREST SECTOR MODELS

Using our analysis of the bilateral trade structure, its dynamic change and the factors that shape it as a basis, we should be able to link national forest sector models in a consistent and realistic way. From an analysis of the past one can hopefully draw some conclusions concerning the direction of change of trade intensities (or trade policy coefficients) under various scenarios for the future, and make certain assumptions about how far such changes can go. This type of information is useful in finding consistent solutions for the set of national models.

5/ See in more detail: Nagy [1969]

National models should have certain common characteristics if they are to be linked consistently as we propose here. They should consist of at least two parts[6]: (a) a forest sector part which yields demand, supply, domestic use, exports, imports, costs and inputs, taking into account the various technologies used and the natural resources of the country; (b) a policy part which includes a number of important policy instruments such as technological change and investment (planning), marketing, subsidies and taxation, price responses, harvesting policies, etc. The two parts of the national models should be linked in such a way that changes in the policy instruments have a consistent and realistic effect on the part dealing with the forest sector and on its information output (exports, imports, costs, etc.).

The policy part of the national models should be devised in such a way that it can receive information both from the trade and the forest sector model, and transform this information into policy changes that could be used to direct the forest sector part of the model. The forest sector model will yield trade balances in forest products at each step of the iteration, and if these surpluses or deficits go beyond a given limit this should induce changes in the policy part of the model which will then be fed back to the forest sector model. (It is arguable whether the use of total trade balances for individual countries has any advantage over the more direct limitation of balances in forest products.)

The trade part of the model should be composed of trade flow matrices with their total export and import vectors disaggregated by commodity groups. This part of the model should receive two types of information as inputs from the national models: total national exports and imports and trade intensity changes (indices showing which of the trade flows are expected to change their intensities, in which direction and by how much). With the help of this information, the trade model can identify major inconsistencies both in national total exports and imports (export and import surpluses, or deficits) disaggregated by commodity groups and in relevant bilateral trade intensities.

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[6] It does not seem to be obvious that the national model should be "closed" in the sense of having all economic activities (other than the forest industry) lumped together.

The inconsistency indications then flow back to the policy part of the national models. It is decided here what policy changes have to be made to reduce the reported inconsistencies. These changes go to the forest sector part, which reacts to them (according to certain rules) to produce new outputs (new values for total exports, imports, costs, etc.). If the policy changes are such that they change trade intensities (e.g., special promotion of exports in certain markets, bilateral price deviations, etc.), they are reported to the trade part of the model, where the trade intensities change accordingly.

This iterative procedure continues until the inconsistencies diminish to a level from which a consistent solution can be computed. This is achieved by first choosing one value for each of the total export and import vectors and then minimizing the deviations of the given trade intensity coefficients from thos of a consistent solution. When we have projected total export ($\hat{X}_{i.k}$) and import ($\hat{X}_{.jk}$) vectors and trade intensity coefficients ($\hat{\delta}_{ijk}$) there are several ways in which we can find a consistent solution satisfying the equations given on page 9. One of the simplest is to apply linear programming in which trade flows $X_{ijk} \geq 0$ are sought such that[7]:

(a) they are consistent with the projected total exports and imports:

$$\sum_j X_{ijk} = \hat{X}_{i.k} \text{ and } \sum_i X_{ijk} = \hat{X}_{.jk};$$

(b) the sume of the squares of the relative deviations of the δ_{ijk} coefficients associated with X_{ijk} flows from the projected $\hat{\delta}_{ijk}$ coefficients is minimised

$$\sum_{i}\sum_{j} \left(\frac{\delta_{ijk} - \hat{\delta}_{ijk}}{\hat{\delta}_{ijk}} \right)^2 \rightarrow \min$$

7/ See: Nagy [1982].

Unfortunately the iteration described above will not always be convergent. If it does not converge, direct intervention must be used to reduce the inconsistencies.[8] It may also happen that the consistent solution produced by the method described above does not seem to be feasible, because it involves changes in trade intensity that are too great, or that move in the wrong direction. In all cases a detailed check and analysis have to be made before a solution can be regarded as acceptable.

As can be seen, price is treated as a policy instrument which can influence both the forest sector part and the trade part of the model, but it is not a unique tool which can or will produce an equilibrium on the market. There are several reasons for this. There are no reliable price statistics, and the unit values which can be observed are very strongly influenced by the product mix, the transportation costs and terms of the transaction in the different countries. If there is perfect competition on the world market, there should be only one price, and consequently the spread of national prices can be regarded as a result of market imperfections distributed very unequally among the trading countries. Comparative advantage, one of the main driving forces of international trade, works through national (or enterprise) cost differences and consequently through profit differences - not through the differences of national prices linked by a unique profit-rate to diverging costs.

However, these considerations concerning the role of divergent national prices do not exclude the possibility that prices could be used as the sole policy instrument to respond to the inconsistencies of the trade model and direct the forest sector model accordingly. Nevertheless, it seems rather unrealistic to assume that both the national governments and the business communities would renounce the use of other policy instruments in an attempt to overcome the inconsistencies reported by their markets.

Andras Nagy
29 May 1982

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[8] There are simple man-machine dialogue methods to do this, see: Nagy [1982].

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