WORKING PAPER

ESTIMATING FOREST PRODUCTS DEMAND AND SUPPLY FUNCTIONS FOR A GLOBAL TRADE MODEL

William McKillop

August 1983
WP-83-73

Department of Forestry and Resource Management,
University of California, Berkeley, CA 94720, USA.

in collaboration with

The Forest Sector Project
International Institute for Applied Systems Analysis

IIASA
International Institute
for Applied Systems Analysis

ESTIMATING FOREST PRODUCTS DEMAND AND SUPPLY FUNCTIONS FOR A GLOBAL TRADE MODEL

William McKillop

August 1983
WP-83-73

Department of Forestry and Resource Management,
University of California, Berkeley, CA 94720, USA.

in collaboration with

The Forest Sector Project
International Institute for Applied Systems Analysis

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
2361 Laxenburg, Austria

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 deals with estimation of demand in wood products. The study aims to serve the needs of global trade modeling, and therefore, the long time perspective as well as the differences in various model

regions have been kept in mind. Theoretical foundations of such econometric forecasting have been considered, and specific preliminary models have been suggested taking into account data which is currently available. Finally, recommendations have been given for developing the data base to improve the demand forecasts.

Markku Kallio
Project Leader
Forest Sector Project

CONTENTS

ESTIMATING FOREST PRODUCTS DEMAND AND SUPPLY FUNCTIONS FOR A GLOBAL TRADE MODEL

William McKillop

1. INTRODUCTION

Adams, Kallio and Seppälä (1982) described the need for a global trade model (GTM), and outlined the general approach to the construction of such a model. Buongiorno and Gilless (1983) describe the modeling of a linkage system for the GTM. Estimation of demand and supply functions for each commodity and for each country or region is an important part of the GTM. In particular, information on supply and demand "shifters" and elasticities are essential inputs to the Buongiorno-Gilless model. The appropriate theoretical basis for estimating supply and emand functions for use in the GTM, (b) indicate those components of the IIASA data base that are readily accessible and relevant for supply and demand estimation, (c) describe preliminary models that have been estimated using the existing data base, (d) recommend ways in which the data base should be expanded, and (e) suggest how the expanded data base can be used to develop more accurate and useful estimates of supply and demand functions.

2. SUPPLY AND DEMAND RELATIONSHIPS

The supply and demand component of the global trade model could be of two distinct types: (A) supply and demand functions that explain the trade flows between each separate pair of trading partners, or (B) one "aggregate" supply function and one aggregate demand function per commodity for each region (or country). Type A requires the estimation for each commodity of numerous relationships of the form described by

McKillop (1973). The McKillop study dealt only with Japanese-North American trade flows in softwood logs and lumber. If a model of this type were to be expanded world-wide it would be very large; and its solution (to obtain forecasts of future trade flows) would be a complex and lengthy process. Type B, on the other hand, requires the estimation of far fewer relationships and yields forecasts of trade flows with substantially less computation. The emphasis in the remainder of this paper will therefore be on the theory and estimation of a type B structure.

2.1. "Total" versus Export/Import Relationship

In terms of making a GTM operational using the type B structure, one need only estimate, for each commodity, a single demand and a single supply function for each region specified in the model, provided forecasts of supply and demand shifters are available from other models or other parts of the GTM. The GTM solution procedure may require as input, parameters relating to either import/export relationships or parameters relating to the total demand and the total supply for each commodity in each region. Some solution procedures, such as the Buongiorno-Gilless model can utilize either form of information. Both types of relationships are discussed below, although the exploratory empirical analysis deals only with export/import functions because of their simpler data needs.

3. THEORETICAL FOUNDATION

The pure theory of supply, of consumer demand for final products, and of producer demand for inputs is well documented in various texts on economic analysis such as Henderson and Quandt (1971), and Varian (1978). It states that:

(1) the quantity of a good supplied is a function of its price, the prices of other goods produced by the supplier, and the prices of inputs used in the production process;

(2) the quantity of a final (consumer) good demanded is a function of the price of the good, the price of all other goods and the level of consumer income; and

(3) the quantity of an input demanded by a producer is a function of the price of the input, the prices of goods being produced, and the prices of other inputs in the production process.

These theoretical constructs must be modified in the following ways before being used as a basis for econometric modeling:

(1) Producer demand functions must be modified to allow the inclusion of level of output of the demanding industry. For example, since lumber and plywood are major building materials it is desirable from an econometric point of view to include level of construction activity as a shifter when estimating their demand relationships. Similarly, because the demand for other forest products such as paper and paperboard is frequently a derived demand, it is appropriate to include the level of industrial production in the specification of various models. Demand

functions in which the level of output of the demanding industry appears as a shifter may be described as "conditional" demand functions. McKillop (1967) gives justification and procedures for modifying basic theory in this way.

(2) Basic supply and demand theory is frequently presented in a static framework with fixed consumer preference functions and technical production functions. For econometric purposes it must be adapted to recognize such things as shifts in production functions due to capacity changes, changes in preferences and user technology and the time-interdependence of consumer/producer decisions. Details are given in McKillop (1967, 1971).

(3) Provision should be made for constructing econometric models which explain either the level of imports of a commodity by a given country, or the level of exports (rather than just total demand and supply). The basic theory of producer supply and demand applies to exporters and importers. A forest products producer who sells in both the domestic and the export market will have a supply relationship in which the quantity offered for export will be a function of the export price (or prices), the domestic price and the price of inputs to the production process. A manufacturer or construction firm that imports wood products without the assistance of an import broker will have a demand relationship in which the quantity of imports demanded will be a function of the import price, the price of his product (or products) and the prices of other inputs to the production process. On the other hand, one may conceive of a conditional demand function where the quantity imported is a function of the import price for the commodity, the domestic price for the commodity and the level of output of the firm.

Alternatively, if imports and exports are handled primarily by import/export firm or brokers, the demand and supply schedules may be specified in a more simple form. The level of imports may be specified as a function of only the import price and the domestic price; and the level of exports as a function of only the export price and the domestic price. McKillop (1973) employed demand and supply relationships which were a combination of the two types. Specification of import demand and export supply is discussed further below.

4. CURRENT DATA BASE

Appendix A lists the type of annual FAO data that is available on disk on the VAX/UNIX system at IIASA. Data from the original FAO "Yearbook of Forest Products" tapes have been grouped into 25 countries or regions, with 25 categories of forest products. Volume of production, imports and exports are provided in metric tons for paper and paperboard products and in cubic metres for other forest products. Value data are available only for imports and exports (in US dollars). Import data is c.i.f.; and export data is f.o.b.

The US producer price index (wholesale price index) converted to 1980 = 100 has also been put on disk to allow deflation of value data. Data on disk cover the years 1966 through 1980. Appendix B describes procedures for retrieving the FAO data and preparing it for econometric analysis.

Staff of the Forest Sector Project (FSP) are in the process of putting on disk, data provided by IIASA's Food and Agriculture Project (FAP) for certain countries on GDP, population and exchange rates.

5. DESCRIPTION OF PRELIMINARY MODELS

Preliminary models were constructed to determine the best way in which the current data base could be utilized to estimate regional import/export relationships, and to clarify future data needs and econometric work. Newsprint was chosen as a sample commodity and data on net volume of trade (QN) was calculated for each region as gross volume of imports (QI) minus gross volume of exports (QE). Data for QN are shown in Appendix C. (To facilitate future analysis they are "stacked", with data for 1966 through 1980 appearing first for region 1 (Africa), followed by data for 1966 through 1980 for region 2 (Canada) and so on.)

Inspection of Appendix C reveals that, except for China, Japan, and Italy, every country was either a net importer in each year of the 1966-80 period, or a net exporter. In China, exports exceeded imports in 1966-69, and imports exceeded exports in 1970-80. In Japan, exports exceeded imports in 1966 and 1974-79. In Italy, exports exceeded imports in 1966-73 and 1977-78. (There may be an error in the data for Eastern Europe for 1975).

Annual data derivable from the current data base includes, for each region (and commodity):

QO = volume of production

QI = volume of imports

VI = value of imports

QE = volume of exports

VE = value of exports

QN = volume of net trade (QI - QE)

VN = value of net imports (VI - VE)

PN = unit value (price, in constant 1980 US$) of net imports (QI-QE/VI-VE)

QC = volume of apparent consumption (QO + QI - QE)

In addition, lagged values of variables may be derived such as:

QN1 = volume of net trade in the previous year

The basic form of the preliminary models was:

(a) for net importers (demand for imports):
log QN = a+b log PN + c log QN1 + d log QC

(b) for net exporters (supply of exports):
log QN = a+b log PN + clog QN1 + d log QO

The justification for these models was as follows.

(a) They made full use of the available data base

(b) The inclusion of lagged net trade (QN1) as an explanatory variable might represent trade "inertia" or institutionalized patterns of trade. Alternatively QN1 could be regarded as representing a distributed lag structure or a partial-adjustment process (Maddala, 1977)

(c) The inclusion of consumption (QC) in the import demand equation, and production (QO) in the export supply equation gave them a partial-reduced form character whereby the demand for imports was conditional on the overall level of consumption of the commodity, and the supply of exports was conditional on the overall level of production of the commodity. This "conditional" specification is likely to be most appropriate where imports and exports are not large relative to total consumption and production respectively.

Variations in the basic model were tried:

(a) without logarithmic transformation of the data, and

(b) by excluding either QN1 or QC or QO from estimated relationships.

Ordinary least squares (OLSQ) was used to estimate the preliminary models using the TSP econometric package (Hall and Hall, 1978). It was recognized that estimates of parameters might be biased because of the presence of endogenous variables on the righthand side and that simultaneous equation techniques should used as more data became available.

Because only 15 observations (1966 through 1980) were available for each country or region, combined cross-section and time-series analyses were conducted in addition to simple time series analyses. Countries were grouped together for cross-section analyses only if they were net importers throughout the sample period in the case of the net import models; or net exporters in the case of the net export models. Those few countries which switched from one category to the other were not included in the import/export groupings. In addition to models based on groups of countries an aggregate world model for net imports was run using, where feasible, each observation that showed net imports (regardless of country). A similar aggregate world model was run for net exports.

As might be expected in an exploratory analysis with a limited data base, only a portion of regression models showed estimated coefficients that were statistically significant or had the sign (+ or -) that one could expect *"a priori"*.

The next section shows the country/region groupings for which regression analyses were conducted, together with elasticity estimates.

6. RESULTS OF PRELIMINARY ANALYSES

Appendix D contains computer printouts for the individual preliminary models listed in Table 1 below. The results presented here are derived from the logarithmic model with all explanatory variables included.

Table 1

Model	Country grouping	Adj. R^2	Elasticity estimate	Student"t" value	Degrees of freedom
A. Net Import Models					
1	West Germany, U.K., Netherlands, France	0.83	-0.018	-0.34	53
2	Latin America, including Brazil	0.95	0.049 (wrong sign)	1.33	24
3	Africa and Asia, excluding Japan and China	0.89	-0.822	-7.46	39
4	Australia	0.17	-0.088	-0.20	10
5	USA	0.79	-0.380	-2.62	10
6	W. Europe	0.91	0.052 (wrong sign)	0.30	10
7	W. Europe and Hungary	0.99	0.351 (wrong sign)	2.35	25
8	All importers	0.94	-0.181	-2.908	194
B. Net Export Models					
1	Finland, Norway, Sweden (Nordic)	0.96	-0.064 (wrong sign)	-1.01	38
2	Canada	0.98	-0.152	-5.33	10
3	Canada and Nordic	0.99	-0.063 (wrong sign)	-1.16	52
4	Oceania and New Zealand	0.90	0.404	2.58	24
5	E. Europe and USSR	0.63	-0.882 (wrong sign)	6.76	22
6	All exporters	0.53	-0.466 (wrong sign)	-4.43	134

Although elasticity estimates are of the correct sign in five out of the eight net import models, only one of the net export models (Oceania and New Zealand) produced an estimate with the correct sign. The persistence of a negative price coefficient in net export relationships indicates that important supply shifters, such as production capacity, have been omitted from the model. This is, of course, not unexpected given the simple nature of these preliminary models. Clearly more complete models of both supply and demand are needed. The following sections suggest ways in which the data base would be expanded and how the expanded base can be used most effectively in econometric modeling.

Before concluding this section the following observations can be made on how the current data base may be more completely utilized:

(a) An attempt should be made to explain levels of gross imports (QI) and gross exports (QE) by using these variables as dependent variables in the preliminary models rather than net imports and net exports.

(b) Some attention might be given to the nature of the price variable (PW) used in the preliminary models. For import models, PN was computed by dividing net value of imports (VI-VE) by net volume of imports (QI-QE). Net value and net volume of exports (VE-VI) and (QE-QI) were used in the case of net export models. One alternative formulation for PN could be a weighted average price, PNA = (VI+VE)/(QI+QE).

(c) Use could be made of 0-1 dummy variables to represent known shifts in patterns of international trade. Alternatively dummy variables might be used to represent individual countries in combined cross-section/time-series analyses. This is the familiar LSDV method described by Maddala (1977).

(d) Another potentially useful technique described by Maddala is Zellner's "seemingly unrelated regression models" in which one seeks to take advantage of the fact that in a combined cross-section/time-series analysis, error terms might be uncorrelated over time but correlated across cross-section units. This option is available on the IIASA VAX through the TSP package.

7. DATA BASE EXPANSION

The variables listed below will be useful in a more complete econometric analysis and are reported by country in the UN Statistical Yearbook for 1979/80 (United Nations, 1981) on the page numbers shown. Items marked with an asterisk (*) are more important.

(a) Population (p.69)

(b*) Index of general industrial production (p.175)

(c*) Index of manufacturing production (p.175)

(d) Value of construction in national currency (p.367)

(e*) Index of construction activity (p.375)

(f) Construction: number of units and floor area (p.379)

(g*) Index of total product at constant prices (p.635)

(h) National income at market prices (p.641)

(i) GDP in purchasers' values -- national currencies (p.641)

(j*) GDP in purchasers' values -- US$ (p.693)

(k) Total national income in market prices -- US$ (p.698)

(l*) Disposable income in market prices -- US$ (p.698)

(m*) Hourly, daily and monthly earnings in manufacturing (p.709)

(n*) Wholesale price index: "producers goods" and "general" (p.713)

(o*) Consumer price index: "all items" (p.720))

(p*) Exchange rates-national currency per US$ (p.754)

(q*) Value of gross output of energy (p.780)

(r*) Production of primary energy in thousands of metric tons of coal equivalent (p.780)

(s*) Total circulation of daily and non-daily newspapers (p.876)

Computer tapes of the Statistical Yearbook compilation are apparently not available but the basic data tapes on which the Yearbook information is based are obtainable through UNIDO. In addition to the above data it is recommended that a determined effort be made to develop a time series for aggregate mill capacity and operating ratios for major exporting countries, particularly for pulp and paper products. Another important supply shifter will be some measure of the accessible and merchantable timber resource in major producing countries. This is likely to be particularly important in estimating supply relationships for roundwood and solid wood products. Lastly an effort should be made to incorporate into the data base, forest product price information provided recently by FAO (1982).

8. FURTHER ECONOMETRIC WORK

It is recommended that the expanded data base be used to estimate the models specified below, using logarithmic transformations of variables, and value data in constant 1980 US dollars. Estimation should be carried out by a combination of cross-section and time-series analyses using TSP's two-stage least squares option where feasible, and grouping countries where necessary to obtain coefficients that are (hopefully) of the correct sign and statistically significant. For the sake of compactness, models for newsprint are specified in most detail and then models for other pulp and paper products are discussed in relation to those for newsprint. Plywood models are discussed through comparison with sawnwood models. For each key product category, models are described for total demand and supply, and gross exports and imports.

A. Total Supply of Newsprint for a Given Country or Group of Countries

Quantity supplied, a function of:

1. Price of newsprint
2. Price of pulp
3. Price of energy and other inputs
4. Wage rates in manufacturing
5. Mill capacities and operating ratios
6. Mill inventories (if available)

B. Total Demand for Newsprint

Quantity demanded, a function of:

1. Price of newsprint
2. GDP and/or disposable income
3. Population
4. Level of newspaper circulation

Additional supply and demand shifters are listed in McKillop (1971).

C. Demand for Imports of Newsprint

This relationship will be similar to that for total demand except that the import price (c.i.f.) should appear on the right-hand side along with the domestic price.

D. Supply of Exports of Newsprint

This will be similar to that for total supply except that export price (f.o.b.) should be included in addition to domestic price.

E. Relationships for Other Pulp and Paper Products

These will be similar to those for newsprint except that the price of newsprint will be replaced by the price of the particular pulp and paper product; and in the demand schedule newspaper circulation will be replaced by level of industrial production and possibly, level of construction activity. McKillop (1971) gives additional details.

F. Total Supply of Sawnwood

Quantity supplied, a function of:

1. Price of sawnwood
2. Price of logs
3. Wages in manufacturing

4. Price of energy and other inputs
5. Mill capacity and operating ratios
6. Mill inventories (if available)

G. Total Demand for Sawnwood

Quantity demanded, a function of:

1. Price of sawnwood
2. Price of substitute materials (including plywood and panel products)
3. Level of construction activity
4. Index of industrial production

Additional information on supply and demand modeling is given in McKillop (1967).

H. Imports and Exports of Sawnwood

Relationships will be similar to total supply and demand except that import price (c.i.f.) will be added to the import demand equation and export price will be added to the export supply equation.

I. Relationships for Plywood

These will be similar to those for sawnwood except that plywood price will be the dominant price variable.

The structure outlined above for newsprint, other pulp and paper products, sawnwood and plywood represents only a starting point for further econometric modeling. Various modifications can be made through the choice of various lagged variables, through the use of proxy or dummy variables and through the use of price as the dependent variable instead of quantity demanded or supplied. Furthermore, full econometric modeling will only be possible when the global trade model is linked to national models. Only then will it be possible to provide the necessary analysis of such things as changes in processing capacities and resource availability.

REFERENCES

Adams, D., M. Kallio, and R. Seppälä (1982) Structural Change in the Forest Sector. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Buongiorno, J., and J.K. Gilless (1983) A Model of International Forest Products Trade. WP-83-63. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Hall, B.H., and R.E. Hall (1978) *User's manual. Time Series Processor.* Version 3,4.

Henderson, J.M., and R.E. Quandt (1971) *Microeconomic Theory.* New York: McGraw-Hill.

Maddala, G.S. (1977) *Econometrics.* New York: McGraw-Hill.

McKillop, W. (1967) Supply and Demand for Forest Products -- An Econometric Analysis. *Hilgardia* (38)1:132. Berkeley: University of California.

McKillop (1971) *Critical Evaluation of Projection Techniques for Paper and Paperboard Consumption.* Rome: FAO Advisory Committee on Pulp and Paper.

United Nations (1981) Statistical Yearbook 1979/80. New York: Department of International Economic and Social Affairs, Statistical Office.

United Nations (1982) *Forest Products Prices 1962- 1981*. Rome: United Nations, Food and Agricultural Organization.

Varian, H.R. (1978) *Microeconomic Analysis*. New York: Norton.

Ward, J.R. (1982) An Introduction to the DB Relational Database Management System. PP-82-1. Laxenburg, Austria: International Institute for Applied Systems Analysis.

APPENDIX A:

DATA FROM FAO YEARBOOK OF FOREST PRODUCTS

commodity	commodity name
1	conif_logs
2	nconif_logs
3	pulpwood
4	fuelwood
5	conif_sawn
6	nconif_sawn
7	panels
8	pulp
9	newsprint
10	other_p_&_w
11	other_p_&_board
12	pulpwood
13	pitprops
14	chips
15	veneer
16	plywood
17	particle_b
18	fibreboard
19	mech_pulp
20	semi_pulp
21	chem_pulp
22	bl_sulphate

23	dissolving
24	other_pulp
25	house_sanit

dimension	dimension name
1	quantity
2	value

element	element name
5	production
6	imports
9	exports

region	region name
1	africa
2	canada
3	usa
4	brazil
5	latin america excluding brazil
6	china
7	japan
8	asean
9	asia excluding china, japan and asean
10	finaland
11	sweden
12	western europe excluding finland and sweden
13	hungary
14	eastern europe excluding hungary
15	australia
16	oceania excluding australia
17	ussr
18	uk
20	netherlands
21	italy
22	france
23	austria
24	new zealand
25	norway

APPENDIX B:

PROCEDURES FOR RETRIEVING AND USING FAO DATA FOR ECONOMETRIC ANALYSIS (via the TSP package)

1. The FAO "Yearbook of Forest Products" data were put on disk on the VAX/UNIX system at IIASA by Ann Francescon, who has also prepared a set of routines using the Database Management System (Ward, 1982) to enable the data to be retrieved in various forms.
2. As indicated in Appendix A, the FAO data is categorized by commodity, region, "dimension" (quantity or value), and "element" (production, imports or exports)
3. To retrieve and prepare data for combined cross-section/time-series analysis using TSP, one first of all calls on a routine "newced" (prepared by Serge Medow) which allows one to select the commodity, element and dimension of interest. This routine "stacks" the data as a column vector, with 1966 through 1980 observations for region 1 in the first 15 rows, then those for region 2 in the next 15 rows and so on.

   The routine "newced" is accessed, after logging on with the login "frances," through the UNIX commands:

   % cd faodb

   % newced

   It is interactive and enables the user to specify (in one pass) lists of commodities, elements and dimensions. For example, the entries

List of commodities: 9

List of elements: 5 6 9

List of dimensions: 1 2

creates column vectors in files named c9e5d1, c9e6d1, c9e6d2, c9e9d1 and c9e9d2 which represent volume and/or value of newsprint production, imports and exports (using the code numbers in Appendix A).

4. The routine "multicol" (also prepared by Serge Medow) combines files containing column vectors into a matrix for use by TSP. For example the command

```
% multicol c9e5d1 c9e6d1 c9e6d2 c9e9d1 c9e9d2 usppi > c9tsp
```

genetrates the newsprint data matrix and adds the file "usppi" to it. The column vector "usppi" contains the US producer price index (repeated for each region) and is used to deflate value data. Multicol gives the name c9tsp to this matrix and stores it in the directory faodb/data.

5 In developing the preliminary models for newsprint, TSP was first used to compute net imports using the file "tspnet" which is in the root directory of the login name "frances". Thus the commands

```
% cd
% tsp 8 = faodb/data/c9tsp < tspnet > tsp.out
% ph net.out
```

will store on file tsp.out net imports of the commodity for each year and each region, and print them out.

6. The net imports printout was used to group countries or regions for the econometric modeling using the TS routines "tspim" for net imports and "tspex" for net exports. Thus the following commands will run a net imports model

```
% cd
% tsp 8=faodb/data/c9tsp < tspim > tsp.out
% ph tsp.out
```

and will store the output in the file tsp.out and then print it out. (The last modification of tspim was to run model A8 -- all importers.)

7. A TSP data file and a net imports file tsp.out was later constructed for coniferous sawnwood. Net imports of coniferous sawnwood have therefore replaced newsprint data on tsp.out.

APPENDICES C and D:

These are computer printouts (on file at IIASA)