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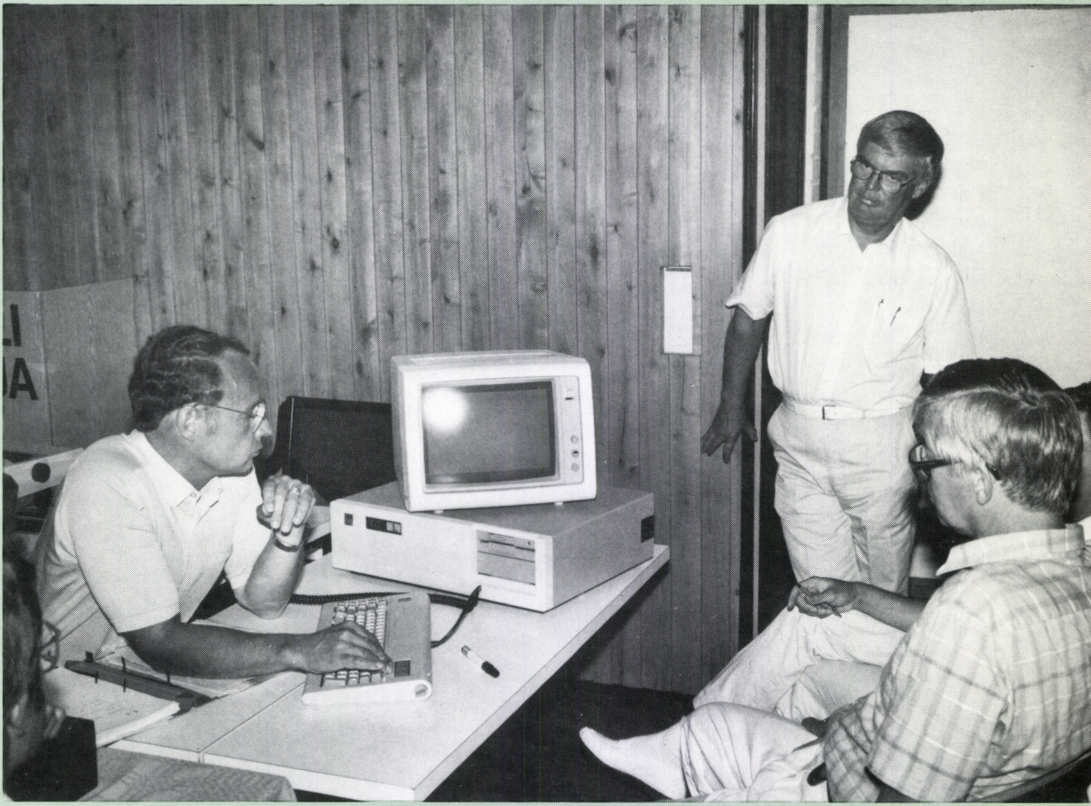

FOREST SECTOR ANALYSIS REVISITED

Proceedings of an International Symposium
July 25—29, 1988, Kerimäki, Finland

Edited by Risto Seppälä

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Forest sector analysis revisited

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PREFACE

This proceedings contains the major part of the papers presented at the "Forest Sector Analysis" symposium, held at Kerimäki, Finland, on July 25-29, 1988. The symposium was a continuation of the sequence of Nordic meetings connected with the IIASA Forest Sector Project.

The purpose of the symposium was to provide participants with updated information on current modeling efforts and their results. The extensive social program was intended to make informal exchange of ideas possible.

The Finnish Forest Research Institute was the primary sponsor of the symposium. Co-sponsors included Ministry of Agriculture and Forstry, Finland, Helsinki School of Economics, and IUFRO Project Group P4.11 - Forest Sector Analysis.

I expess my gratitude to the participants and the contributors of this proceedings. I wish to extend my special thanks to those who hosted participants and their families during visits and excursions.

Risto Seppälä
Editor of the Proceedings

FOREST SECTOR ANALYSIS SYMPOSIUM
25 - 29 July, 1988
Kerimäki, Finland

MONDAY, July 25

8.00 Departure by bus from Helsinki Railway Station

9.45 Visit to forest industries (Kymmene Company)

12.00 Lunch (will be provided)

17.00 Arrival at Kerimäki; check-in at the hotel

18.00 Registration

18.30 Departure by bus from the hotel

19.00 Reception of the Ministry of Agriculture and Forestry at Olavinlinna Castle

20.30 Opera "Carmen" at Olavinlinna Castle

20.30 Departure by bus from Savonlinna to Hotel Herttua for those not going to the Opera

23.30 Departure by bus from Savonlinna to Hotel Herttua for those going to the Opera

TUESDAY, July 26

8.00 Registration - Hotel Herttua

8.30 Welcome and Opening Remarks - Risto Seppälä, The Finnish Forest Research Institute

SESSION I Modeling of forest industries

Moderator: Peter A. Cardellichio

8.40 **Identification of Changes in Strategy and Structure of Forest Industries** - Pentti Sierilä, The Central Association of Finnish Forest Industries

A Decision Support System for the Forest Industry - Stig Byström & Lars G. Samuelsson, Mo och Domsjö AB; Lars Lönnstedt, Swedish University of Agricultural Sciences

10.10 COFFEE BREAK

10.30 **Alternative Scenarios for the Development of the Finnish Forest Sector** - Markku Kallio, The Helsinki School of Economics and Business Administration; Heikki Seppälä & Risto Seppälä, The Finnish Forest Research Institute

The Impact of Trade Barriers and Subsidies to the Trade of Forest Products between Industrialized and Developing Countries - Esko Pyykkönen, The School of Economics and Business Administration

12.00 LUNCH

SESSION I Continued

Moderator: Pentti Sierilä

14.00 **Modeling Technological Change and Fiber Consumption in the U.S. Pulp and Paper Industry** - James L. Howard, Peter J. Ince, Irene Durbak & William J. Lange, Forest Products Laboratory, The U.S. Forest Service

Determinants of Capacity Change - Anders Baudin, Kenneth Libäck, Göran Lönner & Hans-Olov Nordvall, Sveriges Lantbruksuniversitet

15.20 COFFEE BREAK

15.40 **Bulgarian Forest Sector Analysis - a Project Development** - G. Raffailov & Ch. Bojinov, Higher Institute of Forestry and Forest Technology, Bulgaria (cancelled)

Comparative Analysis of Forest-Based Development in Finland and Developing Countries - Matti Palo, The Finnish Forest Research Institute

17.00 BREAK

18.30 DINNER

20.30 SMOKE SAUNA - Hotel Herttua

WEDNESDAY, July 27

8.00 Departure by bus from Hotel Herttua

8.30 Visit to Punkaharju Forest Research Station & Research Forest - Anna-Maija Niskanen, The Finnish Forest Research Institute

10.00 Departure by boat from Punkaharju to Savonlinna

Timber felling and floating operations (Enso-Gutzeit Company)

Lunch (will be provided)

14.30 Arrival at Savonlinna

14.45 Visit to Olavinlinna Castle

15.45 Free program in Savonlinna

20.00 Departure by bus from Savonlinna to Hotel Herttua

THURSDAY, July 28

SESSION II Modeling of the components of the forest sector

Moderator: Göran Lönner

8.40 **IIASA'S Adic Rain Model (RAINS)** - Juha Kämäri, Ministry of Environment

MELA - Forest Management Planning System - Markku Siitonen, The Finnish Forest Research Institute

10.10 COFFEE BREAK

10.30 **METSO - Forest Income Calculation System** - Pentti Hyttinen, University of Joensuu

Expected Prices and the Felling Decision - Peter Blandon, City of London Polytechnic

12.00 LUNCH

SESSION III Methodological advancements in forest sector modeling

Moderator: Don Roberts

14.00 **Some Developments in Modeling of International Trade in Forest Products** - Markku Kallio, The Helsinki School of Economics and Business Administration

A Review of Methodologies for Modeling Bilateral Trade Flows - Peter A. Cardellichio & Darius M. Adams, CINTRAFOR, The University of Washington

15.20 COFFEE BREAK

15.40 **A New Systems Analysis Paradigm for Forest Sector Modeling and Analysis** - Thomas C.Marcin, Forest Products Laboratory, The U.S. Forest Service

The Use of Artificial Intelligence Techniques in Modeling Forestry - Hannu Saarenmaa, The Finnish Forest Research Institute

18.00 BREAK

19.00 DINNER

20.00 SAUNA - Punkaharju Research Station

FRIDAY, July 29

9.00	Departure by bus from Kerimäki
9.30	Visit to Retretti Art Center
13.00	Lunch
17.00	Arrival at Helsinki Railway Station

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A DECISION SUPPORT SYSTEM FOR THE FOREST INDUSTRY.

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Lars Lönnstedt, Swedish University of Agricultural Sciences, Uppsala, Sweden.
Lars G Samuelsson, Mo och Domsjö AB,Örnsköldsvik, Sweden.

ABSTRACT.

This paper describes a "Decision Support System" based on mathematical models, reflecting the relative competitiveness of manufacturers of forest products in different business environments and the viability of their production facilities and product-mixes. The system contains two parts, the Environment Model, describing the conditions in the environment such as the variation in production capacity and product prices. The Local Industrial Model describes the impact of changes in the local industrial structure on the global economic result from a group of production units in a company, operating under specific conditions with respect to technology and raw-material supply. The system has been used in the pulp and paper industry for the evaluation of the profitability of existing and planned production units.

INTRODUCTION

By interaction between production capacities, inventories and other variables describing the current business climate, **the Environment Model** generates input data to the Local Industrial Model(Fig 1). The Environment Model is a continous simulation model.

The Local Industrial Model computes the optimum product flows in an industrial structure at given costs for production and marketing. The model is based on linear programming technique.

The Local Industrial Model, can be used for calculations of the effects of changes - for instance closures or expansions of production facilities - in the industrial structure of a company (Fig. 1). In this way the marginal effects of structural changes on the global economic result of a group of factories in a company can be estimated for long term planning purposes.

Both models can be run on a personal computer. The system was developed by the Mo och Domsjö Corporate Planning Group.

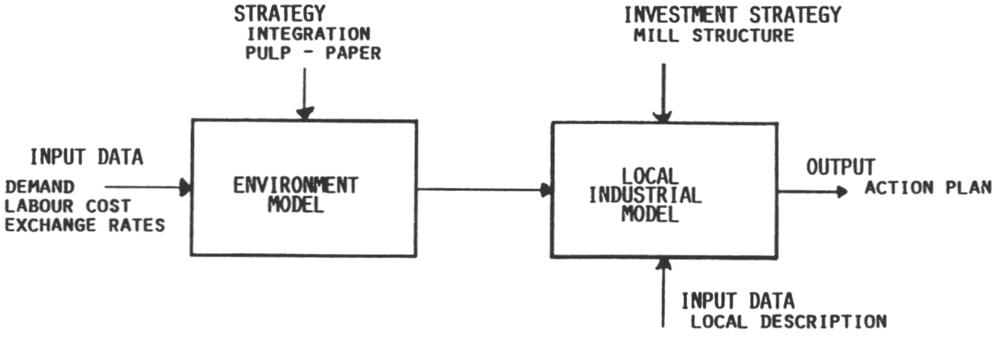

Figure 1. Principle outline of the Decision Support System.

THE ENVIRONMENT MODEL

Introduction

One purpose of the Environment Model is to generate data for the Local Industrial Model, for example development of the relative product price for the coming 10-20 years. (**Relative product price** is defined as the market price relative to a theoretical long term price, covering all costs including capital costs.) The Environment Model can be used also for translating long term forecasts to a company context.

The development of the relative product price as well as other output data depend on (a) input data, (b) applied strategies and (c) control mechanisms of the model (Fig. 1). The development of demand, labour costs and exchange rates are examples of input data . An example of a strategy applied in the model for Sweden is continued integration of pulp and paper production, A consequence of this is that Swedish pulp and paper companies prefer to employ capital in new paper machines rather than increase the pulp capacity. The structure of the model, an example of a control mechanism as well as an example of a model run, will be presented in the following text.

The model belongs to the family of forest sector models, that is to say the model system includes consumption, market for the forest industrial products, capacity and production, roundwood market and forestry (see for example Lönnstedt & Randers 1979, Adams & Haynes 1980, Cohan 1982, Kallio et.al. 1986, Kishine 1986).

The Environment Model describes the Swedish forest sector as well as competing sectors. The main focus is bleached kraft representing also other types of chemical pulp. Mechanical pulp as well as wood-based boards are included in the model but in a simplified way. The lumber industry is modelled in the same detail as the chmeical pulp industry, the reason being the competition between the Pulp Industry and the Sawmills in the roundwood market, at least for a part of the roundwood supply. As a reference for the competing forest sectors, the US South is used for bleached kraft and Quebec (Canada) for lumber.

Model Structure

Figure 2 illustrates the system structure of the model. The main parts of the system consist of (1) the Swedish forest sector, (2) competing forest sectors and (3) the product market. (A full length description of a similar model system can be found in Lönnstedt, 1986). It is on the market, in our case Western Europe, that the different producers meet and compete with eachother for market shares. The long term development of the Swedesh forest sector, i.e. production capacity and cutting levels, will depend on how competitive Sweden will be relative to other forest sectors.

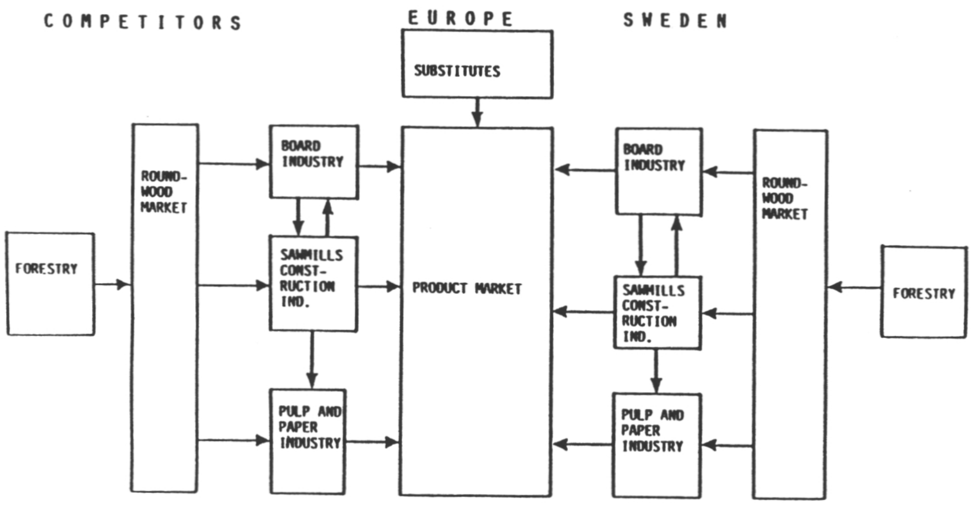

Figure 2. Model structure.

However, the development of the Swedish forest sector is not just a question of competitiveness relative to other forest sectors. It is also a question of competition between forest products and substitutes such as plastics and metals.

Each forest sector consists of (a) the industry, (b) the roundwood market and (c) forestry. In the roundwood market module, actual supply and prices are calcutated from potential demand (coming from the industrial module) and potential supply (coming from forestry). The industry consists of board, lumber and pulp producers.

In this version of the model the user defines the future consumption development rather than using a demand function. In the next version, now under development, the paper industry will be included.

Control Mechanisms

The control mechanisms are fundamental for the results of the simulations. They should reflect the decision processes and the resulting development taking place in reality. They should take into account the various delays in the decision processes that often arise in the managing of industrial activities. The decision makers in different parts of the system need time to understand the ongoing development; after a decision has been taken, a certain time will elapse before the measures taken will give full effect etc. The decisions taken will never lead to perfect control, and the results will be that prices, capacity, production and cutting volumes will oscillate around the target levels. These phenomena should be simulated by the Model.

In the following we will describe one of the control mechanisms as an example.

Production Capacity

In the long perspective production capacity must correspond to consumption. The control machanisms to maintain this balance in the model can be described in the following way:

Decisions regarding spending of capital in new production capacity are taken as long as the market conditions appear to be good and capital is available. After some years the effect of such decisions has lead to increased capacity and production, constituting a change in the market situation. Such changes are reflected in price and profit levels. There is a delay in this control mechanism. Adjustment is a matter of several years or perhaps a decade (Fig. 3).

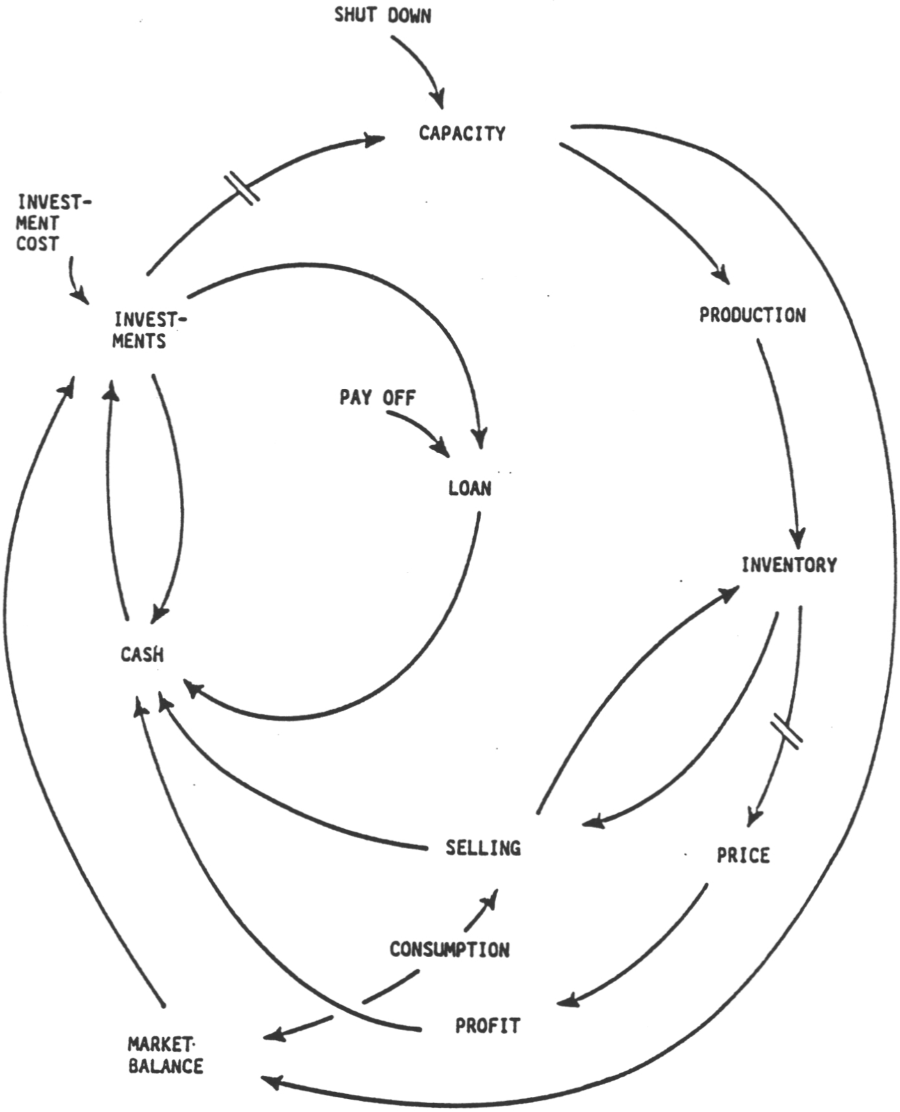

Figure 3. Control mechanism for production capacity.

Planning and building time for a new pulp or paper mill is several years. Decisions to expand capacity will be taken at different points in time by different company boards. This makes forecasts, made by individual companies uncertain, and periods of overcapacity in the market may arise.

A decline in demand in an active business climate is often considered as a temporary phenomenon and not as a beginning of a recession. The delay in reaction by the management may be caused by a too optimistic view of its own company's ability to meet more difficult times. However, as the situation develops, more and more company managers will be convinced that the market change has come to stay. This creates hesitation in the decision process. Capital will no longer be easily available for expansion projects in the industry. Unprofitable production units will be closed and gradually, the market situation will once again improve as a result of a new balance between supply and demand. The prices will start to increase as well as the profit. Capital for expansion projects will again be available.

Model Runs

A forecast from RISI dated 1987 has been used as input data for chemical pulp consumption. The consumption in Western Europe was estimated to increase from about 26 million tons in 1990, to 31 million tons at the turn of the century, i.e. an average annual increase of less than 2%.

The average annual increase of labour costs in the US South during the 1990's is estimated at 5 - 6% (op.cit.).Our assumption is that the Swedish labour costs will increase somewhat more, 7 - 8% per year as an average. In total, the production costs (including transportation costs to Northern Europe but excluding capital costs) are assumed to be about 10% higher in Sweden than in the US South during the 1990's. We have not taken into account a close down of Swedish nuclear plants and its effect on the domestic energy prices. The exchange rate between the Swedish Crown (SEK) and the US Dollar (USD) has been estimated at 6.50 SEK/USD as a base case. In two reruns the exchange rates 7.50 and 5.50 SEK/USD have been used.

Figure 4 shows the relative price development for Swedish producers of bleached kraft pulp. According to the model run and with the given input data, the next decade will not be as profitable for the Swedish forest industry as the 1980's. One important reason for this development is the change taking place in the model market. This change can be explained by high profits for the pulp producers especially in the late 1980's. Industries competing with the Swedish pulp producers will use a part of their profits for pulping capacity expansions that will be effective in the 1990's.

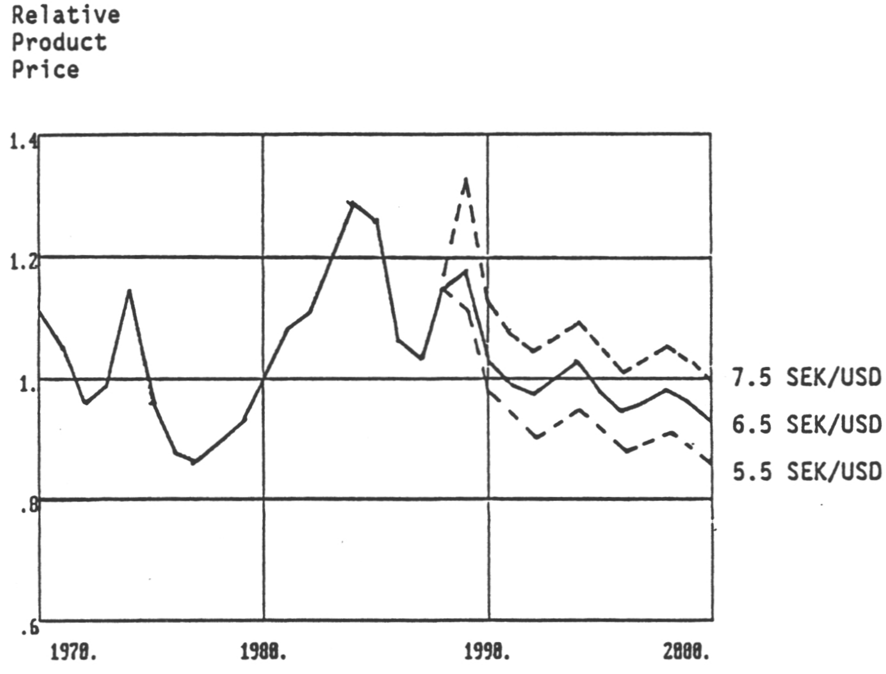

Figure 4. Relative price development for Swedish producers of bleached kraft pulp, with different assumptions for the exchange rate between the Swedish Crown and the US Dollar.

If the exchange rate between the Swedish Crown and the US Dollar stays around 6.50, the 1990's will be fairly good for the Swedish producers according to the model. All costs including capital costs will be covered most of the time. If the exchange rate will be as high as 7.5 SEK/USD, the profit level will be even higher. However, the situation will slowly get worse, and if the exchange rate will be as low as 5.5 SEK/USD, some of the Swedish producers will have serious problems and we can expect that some mills will be closed down.

THE LOCAL INDUSTRIAL MODEL.

Functionning and Applications.

The purpose of **the Local Industrial Model** is to describe how a group of industrial production units reacts as a whole to internal changes in its structure and to external changes in the business environment.

The Industrial Model calculates the maximum **operating profit** that can be achieved by a certain industrial structure under certain conditions. Operating profit in this case is defined as the difference between revenue and costs including interest on working capital. This difference - **the contribution** - should cover the required return on capital employed including depreciation. The maximum operating profit is used as a measure of the potential of the studied structure.

By applying more and more strict restrictions, the character of the model is changed from being an optimizing model to being a simulation model. Too severe restrictions would make this technique of little value for long term planning purposes. However, certain restrictions must be applied even in the long term planning, such as availibility of wood, market demand for products and capacity of the production equipment. The model identifies the bottlenecks in the industrial structure and evaluates the effects of the restrictions.

The Industrial Model is suitable for the evaluation of effects of changes in the structure, for instance closures of production units, expansion of existing units and installation of new units. Such changes affect the total result of the operation considerably. Extensive changes in wood consumption, in market shares etc may be the result.

To evaluate the contribution from one production unit to the total result of the group of units, two optimizations are done - one with the studied unit included in the structure, one witout. The difference between the results is a measure of the contribution from the studied unit to the result of the company, **the marginal contribution (Fig 5)**. If this contribution is high enough to cover the required return on the capital employed in the unit,and the current capital expenditures in the operation, the unit is profitable. If not, the unit is a burden for the company.

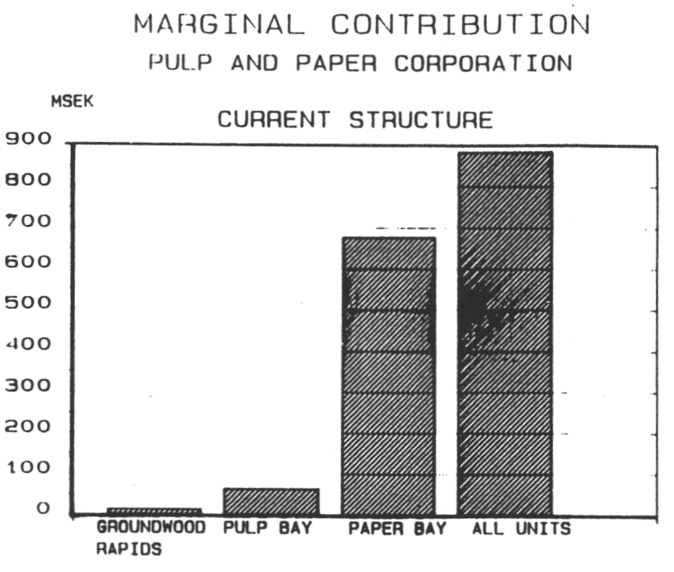

Figure 5. An example of the marginal contribution for a company with three producing units.

In a similar way the effect of the installation of new units can be studied. Two optimizations are done, one with the original conditions in the group, one with the new unit included. If the increase in the result of the group - the marginal contribution - is high enough to give an acceptable return on the capital required for the installation of the new unit, it can be considered to be profitable for the group.

In certain cases the effect of a change in the structure can be so great that different conditions must be chosen for the alternative calculations. For example, if the change in the structure would be the closure of a coating plant, the change would result in the loss of a major part of the market for a paper machine in the remaining group, namely the machine that supplied the coating plant with base paper. The result of this calculation could be misleading. The market conditions in the two calculations should be different. The closure of the coating plant must be connected with the development of a new market for uncoated paper from the remaining paper machine.

For the purpose of long term planning, different scenarios including different events in the development of the industrial group can be studied. Potential markets can be identified for existing and planned production units, forecasts for costs and prices can be made and used for the calculation of the operating profit for the group each year during the planning period. Capital requirements in the existing and planned units must be specified anually. From these data, the profitability of alternative scenarios can be evaluated. The return on the capital employed can be calculated or the financial strength of the group can be calculated for each year and given in the form of a traditional balance sheet.

System Requirements on the Model

A Pulp and Paper industry requires raw-material, such as wood, chemicals, and energy for its operation. In the industrial processes the raw-material is converted into finished products to be sold in the market-place. In the industrial processes costs are incurred, such as labour costs, capital costs, depreciation etc. The capacity at which the various products can be manufactured is limited by the available equipment in the industry. The amount of products that can be sold in the market-place is limited by the demand for the products. Given certain conditions in the industry and its environment, the optimum production rates and product mixes could be determined. However, this problem can be very complex even for a normal size Scandinavian pulp and paper industry.

Varying Prices

Raw-material such as wood is purchased from large areas. A big pulping unit in north Scandinavia receives its wood from the whole Scandinavia and even from the countries around the Baltic. The wood cost is therefore varying with the amount used. An example of wood prices as a function of the amount used in shown in **Table 1.**

TABLE 1.
WOOD COST AS A FUNCTION OF VOLUME.

	VOLUME, 1000'm^3	Kr/m^3
SOFTVOOD	1000	340
SOFTVOOD	1000	380
SOFTVOOD	1000	420
HARDVOOD	500	320
HARDVOOD	500	380
HARDVOOD	500	450

Prices of the finished products vary in a similar way. Increasing market-shares often results in lower prices. Less attractive markets are served resulting in higher transportaion costs etc. An example of market specification for one product is given in **Table 2.**

TABLE 2.
THE MARKET FOR HARDWOOD PULP.

CUSTOMER	A	B	C
PRICE,Kr/TON	3600	3400	3200
CREDIT TIME,DAYS	30	30	30
MIN QUANTITY,%	50	50	0
VOLUME 1988,TON	50	100	100
VOLUME 1989,TON	55	105	105
VOLUME 1990,TON	60	110	110
INCREASE,%/YEAR 1991+	5	5	5

The fact that cost and revenue vary with the quantities of products used or produced, leads to the conclusion that production units are not "additive" with respect to profitability. If two pulp mills are located in the same geografic area and buy raw-material from the same suppliers, their economic results can be different if they are considered to be part of the same company, trying to maximize the economic result of the two units together, or if they are considered to be two separate entities. The environment stipulates also the capital requirement in the operations and the cost of capital (interest).

Mathematical Formulation and Model Structure.

An analysis of the pulp and paper processes show that most relations can be described by linear equations, and the optimization can therefore be done by linear programming. Variables in the mathematical model are the flows of raw-material, semi-finished and finished products. Two types of relations exist - **mass and energy balances** and **restrictions.**

A number of **balances** connect the different processes and production units, controlling the amounts of mass and energy used.

The **restrictions** are expressed by mathematical unequalities. Examples of restrictions are maximum production capacity, available production time, potential market volumes etc.

The **Objective Function** consists of a great number of variables describing the revenue and costs of the operation. It is a measure of the operating profit. The Model computes the values of all variables for a maximum value of the Objective Function and thus a maximum profit for the operation

The Building Blocks

To create flexibility in the use of the Industrial Model, it has been **constructed in the form of Building Blocks.** Each production unit in the industrial structure is represented by a building block in the Industrial Model **(Fig 6)**. A block is a geografically defined unit. Processes in the block have the same costs for raw-material, energy, labour etc. They are often integrated without extensive stocks of semi-finished products. Parts of a block cannot exist separately, as the products from these processes cannot be sold in the market.

Blocks representing the different production units can be connected to other blocks and/or to raw-material sources and markets for finished products. Connections between blocks correspond to real transports between the production units and to the customers in the market-place. All flows of raw-material and products can be identified in the model and compared to measured flows in the operation. Costs related to these flows are part of the Objective Function. All flows are controlled by the restrictions defined in the Model.

A block consists of **stations (Fig 7)**. A station is a part of the production chain - a paper machine, a re-winder, a recovery unit etc. The stations in a block must be described in such a detail, that the differences in the production conditions for the various products are reflected in the calculation results. Different products require different production time, raw-material and labour. This must be reflected in the cost for the manufacturing of the products.

The stations are characterized by a number of parameters such as maximum operating time, labour requirement, capital in equipment and the corresponding depreciation. An example is given in table 3.

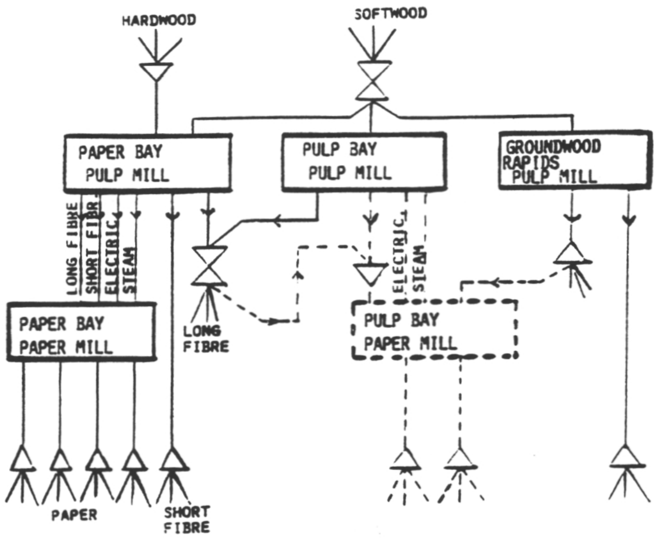

Figure 6. Building blocks in the Industrial Model

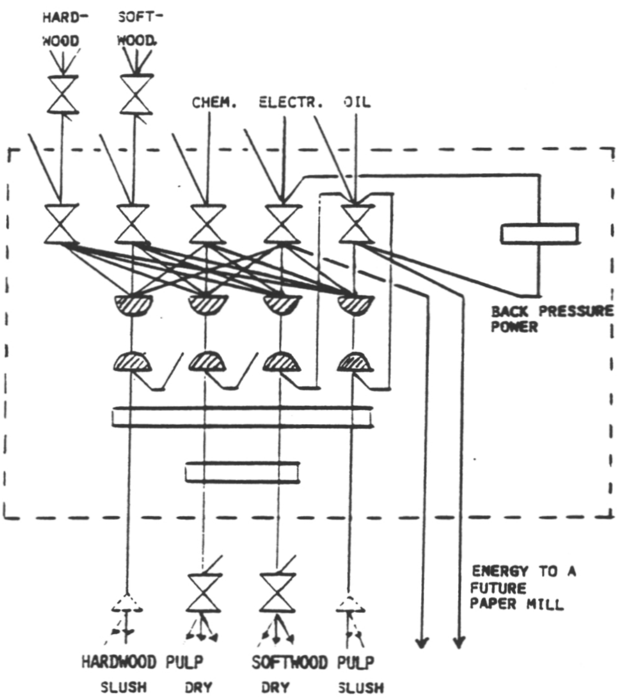

Figure 7.Example of stations inside a building block (pulp mill).

TABLE 3.
FIXED COSTS, PULP BAY PULP MILL.

	WOODYARD	P U L P I N G SOFTW/HARDW.	DRYING	RECOVERY
TIME, H	15000	7500 /7500	7500	15000
CAPITAL,MKr	100	500 / 400	50	250
DEPREC'N,MKr	20	45 / 40	25	50
W'ING CAP,KKr	100	100 / 100	100	100
FIXED COSTS,KKr	75	75 / 75	75	25
MAN-YEARS	100	250 / 250	150	100
MAN-COST,KKr	200	200 / 200	200	200
CAPACITY %	100	100 / 100	100	100
EXIST	1	1 / 1	1	1

Specification of Products

The Industrial Model deals with two different types of products - **Production Products** and **Market Products.** The Production Products are those manufactured in a certain block. Different Production Products can, from the marketing point of view, be the same Market Product, but they have been produced in different equipment and incur different production costs. A Production Product can be further processed into another Production Product, for instance Uncoated Paper can be coated and become Coated Paper.(Internal deleveries and internal prices do not exist in the Industrial Model). The relations between production products and market products are given in a table.

The various Production Products are specified with respect to consumption of raw-material, energy etc. in **Product Specification Tables (Table 4)**. For certain products also the amount of "broke" is specified. From these tables the **variable production cost** for the different products are calculated. The variable capital cost, interst on current assets, is calculated from credit times, inventories, debts to suppliers etc.

TABLE 4.
PRODUCT SPECIFICATION, PULP
PULP BAY KRAFT MILL.

	SOFTWOOD PULP SLUSH	SOFTWOOD PULP DRY	HARDWOOD PULP SLUSH	HARDWOOD PULP DRY
SOFTWOOD, M^3/TON	5.00	5.00	0.20	0.20
HARDWOOD, M^3/TON	0.00	0.00	3.60	3.60
ELECTRICITY, KWh/TON	700	800	700	800
ENERGY, LITERS OF OIL	-225	-135	-180	20
KNOTTER PULP, Kg/TON	-25	-25	-25	-25
TURPENTINE, Kg/TON	-20	-20	-20	-20
OTHER COSTS, Kr/TON	200	215	230	245

In the **Fixed Cost Tables** the different stations of the production units are described with respect to production rates. In these tables the time requirement is expressed in hours per ton of each product. The total time for the production of the different products is limited by the restriction giving the total availabel time in the station. From the data in these tables the **fixed costs** are calculated (labour, maintenance, depreciation and capital interest).

The revenue and the variable costs are connected to the various products. The Objective Function is calculated from the revenue and the variable costs. The fixed costs are related to the industrial structure and can be eliminated only if the production unit is closed.

Model Runs

The report from an optimization of an industrial structure contains a description of the **Product Mix,** i.e. the optimum amount of the different products that should be produced. The report also give a more comprehensive description of the products with respect to its consumption of raw-material, energy, labour etc. The design of the Industrial Model makes it possible to calculate the total consumption of wood, energy, labour etc in the entire, integrated production sequence. For example, for coated paper, the total consumption of wood, energy etc in all involved processes - the wood yard, the pulp mill and the paper mill - can easily be calculated. This makes it possible to relate the results from production of a product or a mix of products to its consumption of wood, energy, labour and to the capital employed. Examples of such **Product Mix Diagrams** are shown in **Fig 8 and 9**. Valuable information can be obtained from these diagrams about the sensitivity of the various products to variation in raw-material cost, i.e. to variations in the business climate.

Implementation of the Model.

A great number of linear programming codes for optimization are available on the market. For this specific Industrial Model the PXMP is used. This code is also able to solve mixed integer linear programming problems.

The flexibility of a linear programming model mainly depends on the system used for the description of the problem, to generate the LP-matrix, to process data and to generate the reports. In this particular case, the system GOT (General Optimization Tool) has been used. GOT consists of three parts, one for the database, one for the matrix generation and one for the generation of the reports. In addition to this, there are modules for the processing of complicated process sequences.

The system is composed by a large number of elements, programmed in the language APL. These elements can be combined in different ways to create building blocks, corresponding to the production units in the industrial structure. This gives the system a great deal of flexibility. For the pulp and paper industry, GOT has been equipped with a number of modules, describing production units such as pulp mills, paper mills, coaters etc.

In the database, all production units as well as the products that could be produced are specifically described in tables. The data in these tables are called for during the calculations. The use of the data is controlled by "name lists". These lists are also used for the generation of the variables for the mathematical model. Name lists can be created and changed dynamically by the program code in the different blocks. This procedure gives the model great flexibility.

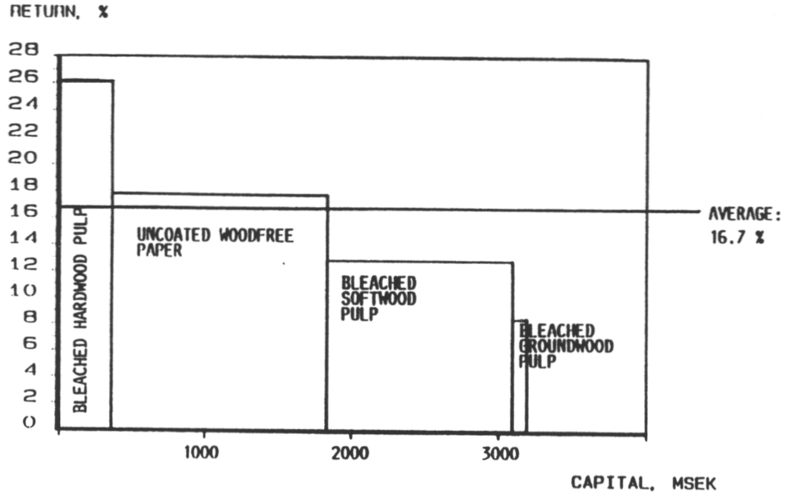

Figure 8. Return on capital.

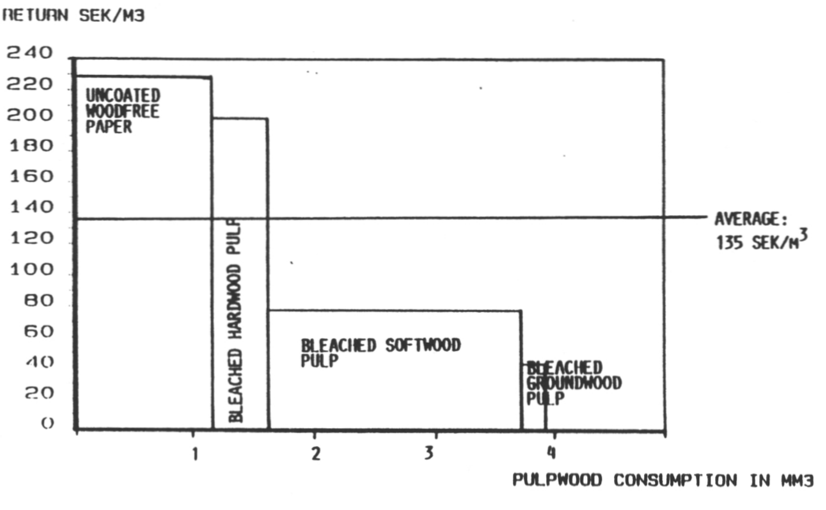

Figure 9. Return on pulpwood

For the model now in use, a database has been created describing the existing and planned production units and the corresponding raw-material and product markets for a perion of 10 years. The model is operated (updating of the database, optimisation and report generation) on a Personal Computer (IBM-RT with AIX operating system and Dyalog APL interpretator). The time required for matrix generation, optimization and report generation, varies between 2 and 5 minutes, depending on the amount of data to be generated in the report. A demonstration version of this model can be operated on a PC of the type IBM-AT. In this case the process time will be longer.

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ALTERNATIVE SCENARIOS FOR THE DEVELOPMENT OF THE FINNISH FOREST SECTOR

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ABSTRACT

The aim of this review is to show, how the Global Trade Model, GTM, and its modifications can be utilized from the point of view of a single country. Finland can be considered as an excellent example for this purpose, because Finland has an active role in the international trade of forest products.

The results show that the GTM-model serves as a good tool for policy analysis also for a single nation. The first results of model runs showed that the price of electricity, exchange rates, timber prices, interest rates, potential trade barriers in EC -region and changes in wood processing technologies were important variables as for the performance and product structure of the Finnish forest industries.

During the work process a "tailor-made" algorithm for solving partial equilibrium models was developed. Without this new algorithm active research and development work with the GTM would have been extremely difficult because of the computer time intensiveness of the MINOS -algorithm originally used with the GTM.

INTRODUCTION

Scenario analysis with the GTM -model started in Finland in 1986. In all seven different scenarios were made with the original IIASA's GTM version. These scenarios analyzed the following topics: changes in stumpage prices, exchange rates, industrial production costs, energy prices, production technology, as well as effects of trade barriers and possiple air pollution damages to Finnish forest sector. The analyses are reported as graduate theses at Helsinki School of Economics (in Finnish only).

As far as a large scale model like the GTM is concerned, testing the model structure, parametrization, constraints and operational charasteristics is a very complex and time-consuming job (Cardellichio and Adams 1987). Therefore, we decided to build a small, two-region equilibrium model to test the applicability of the market economy module of the GTM to the Finnish conditions.

This model is called MESTA (see Seppälä and Seppälä 1987). Besides the validitation of the GTM, the dynamic version of MESTA has also been used for other purposes, e.g. to evaluate the so called Forest 2000 Programme made by the governement of Finland (Seppälä and Seppälä 1987). A "tailor- made" program for solving linearly constrained partial equilibrium models (Kallio and Salo 1987) was also introduced with MESTA. This program allows the GTM to be solved efficiently in a micro computer environment within a practical precision tolerance.

The next step in the study program was to update the data base of the GTM from 1980 to 1985, and reorganize the product assortment of the forest industry module to correspond to the structure of the Finnish forest industry. Experiences and results of scenario analyses made with this model version are documented in the following sections.

MODEL

The basic structure of the model is the same as in the IIASA's GTM model (Kallio et.al. 1987). The data basis has, however, been changed from 1980 to 1985. In addition, the product assortment of the model is slightly different: "household and sanitary paper" group is included in "other paper and board" cathegory and "printing and writing paper" group is segregated into "wood-containing printing and writing paper" and "wood-free printing and writing paper" grades. This is because household and sanitary papers play a minor role in the Finnish forest industries and, on the other hand, printing and writing papers are important both in quantities and in wood raw material qualities.

SCENARIOS

In addition to the base scenario, we have, so far, experimented seven different scenario topics with the updated GTM -version. These are as follows: (1) exchange rate variations (Finnish Mark against all other currencies), (2) changes in the Finnish timber supply, (3) changes of interest rates in the Finnish capital markets, (4) trade barriers of paper exports to the EC -region, (5) changes of the wood processing technologies and investment behavior of the industry, (6) evaluation of the Forest 2000 -programme, and (7) the effects of the Finnish energy policy alternatives. As an example of the scenario analyses we introduce here the energy policy scenario.

Energy policy scenario

Continuous increase in the degree of refinement has - especially in paper production - meant an increased energy intensity in the industry (Figure 1). The price of electric power has became a more and more critical factor. For example, in some wood containing paper qualities the cost share of purchased energy is 10 to 15 per cent of the sales price of these paper grades.

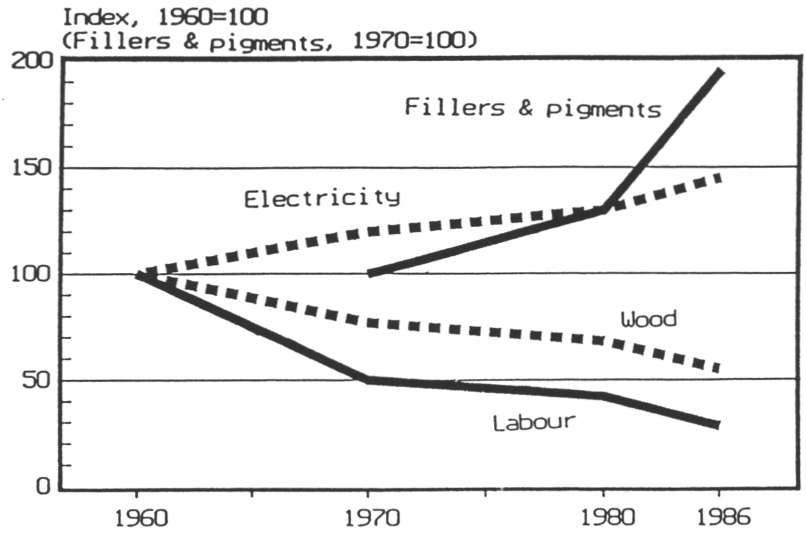

Figure 1: Input/Output -ratios in the Finnish forest industries in 1960-1986 (Sources: Pekkanen M. 1988, Seppälä H. 1988).

In Finland energy policy is now and then topic number one in political debate. The basic issue is the construction of nuclear power plants. Electricity production based on nuclear power is clearly cheaper than that based on fossile fuels. However, experiences, first from Harrisbourgh, and then from Zernobyl turned public opininion against nuclear power.

More than one third of the total deliveries of electricity in Finland is now based on nuclear power. The share of the forest industries out of total electricity consumption in Finland is almost one third.

Assumptions

Two factors are varied in the energy scenarios. The first one is the market price of fossile fuels. This is beyond the political control of Finland.

The second factor is the choice of the method with which the additional electricity supply is produced: fossile fuels or nuclear power. This is under the control of the Finnish energy policy.

By varying these two factors we have ended up with the following four scenario assumptions:

1. The price of fossile fuels will remain at its present low level and the additional electricity will be produced with fossile fuels.

2. The price of fossile fuels will remain at its present low level and the additional electricity will be produced with nuclear power.

3. The price of fossile fuels will double by 1990 and the additional electricity will be produced with fossile fuels.

4. The price of fossile fuels will double by 1990 and the additional electricity will be produced with nuclear power.

As a result of these four alternatives we get electricity price paths shown in Figure 2. The structure of electricity production capasity is assumed to stabilize so that it has no effect on electricity price development (ceteris paribus) after 2000. In the base scenario we assume, that the structure of the electricity production capacity will not alter from that of the 1980s and the price of electricity remains the same as in 1985.

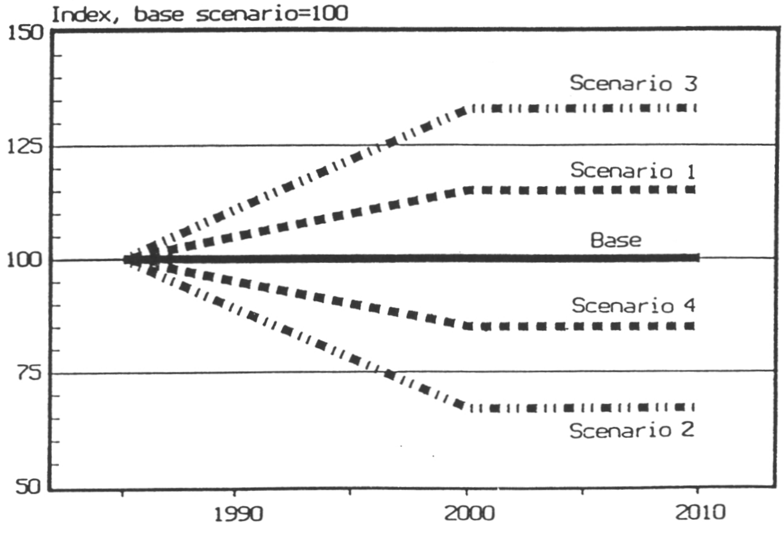

Figure 2: Price of purchased electricity in 1985 - 2000 in energy policy scenarios.

These scenario assumptions are extremely simplified. For example, we ignore the reactions of competitors both to the Finnish energy policy desicions and to changes in prices of fossile fuels. We also ignore the effects of substitution of the demand for the forest industry products, when the price of energy changes.

Results

In the following, energy scenario results will be presented in relation to the base scenario. Only the extreme alternatives 2 and 3, as well as the base scenario, are shown.

Figures 3 - 5 indicate the very important role of the electricity price development for the Finnish forest industries. However, the effect to domestic cutting quantities remains quite small (Fig. 3). The reason might be that timber supply curves - as Cardellichio and Adams (1987) argue - are too steep for long-run resource analysis. This is also the case in our base scenario.

The last two decades in the history of the Finnish forest sector show also a similar development: cuttings have remained at a steady level even though forest industry production has more than doubled.

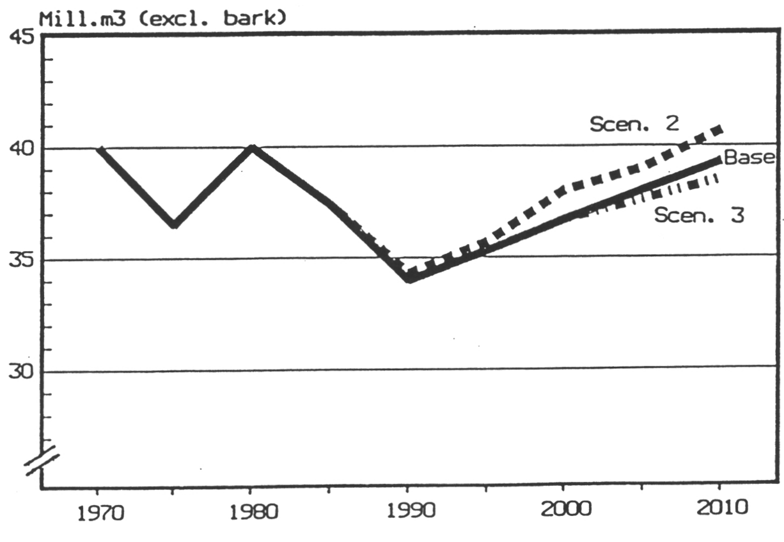

Figure 3: Timber removals for industrial use in energy policy scenarios 2 and 3 and in the base scenario in 1985 - 2010

The forest sector adjusts to inelastic timber supply curves through foreign trade of roundwood and market pulp. This (plus diminished use of wood for household fuel) is actually what has happened during the last two decades. Since the mid 1960s net import of wood has increased from 2 to 4,5 million m3 (including bark), where as export of market pulp has decreased from 2 million tons to 1.5 million tons.

In scenario 2 corresponding to the cheapest electricity price (-33 per cent compared to the base scenario) Finland would become net importer of pulp by year 2000. In scenario 3 which corresponds to the highest electricity price (+33 per cent) pulp export would double in 2000 compared to the base scenario.

The reaction of sawnwood production to the rise of electricity price is interesting. In the high electricity price scenario the production is larger than in the base scenario (Fig. 4). This is simply because the high price of electricity diminishes the use of wood in pulp and paper industry, and as a result presses the price of wood down. In sawnwood processing the need for electricity is low. The reduced wood price overcompensates the increased price of electricity and makes sawmilling more profitable than in the base case.

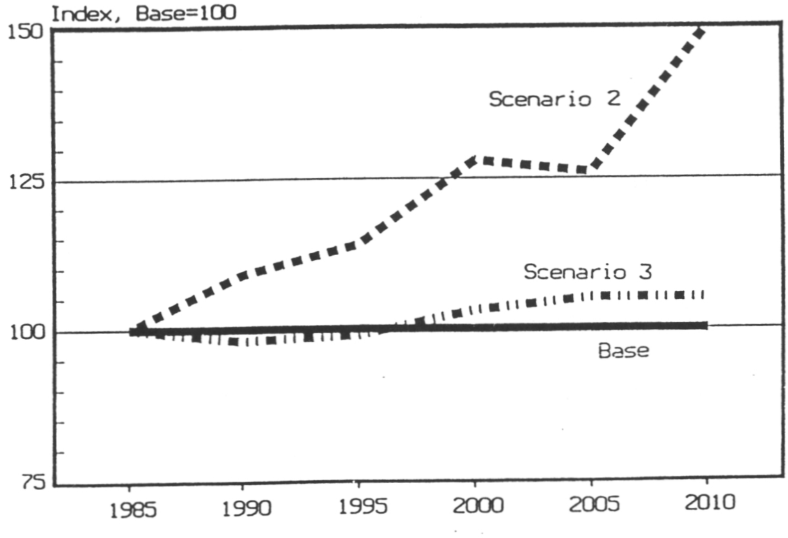

Figure 4: The production of sawnwood in energy-policy scenarios 2 and 3 compared to the base scenario in 1985 - 2010

In the paper industry newsprint production seems to be extremely sensitive to electricity price changes. This is mainly because in Finland the share of mechanical pulp is very high in the neswprint furnish and mechanical pulping is very electricity intensive. The role of the electricity price is also strategic in the Finnish paper industry as a whole, as is seen in Figure 5.

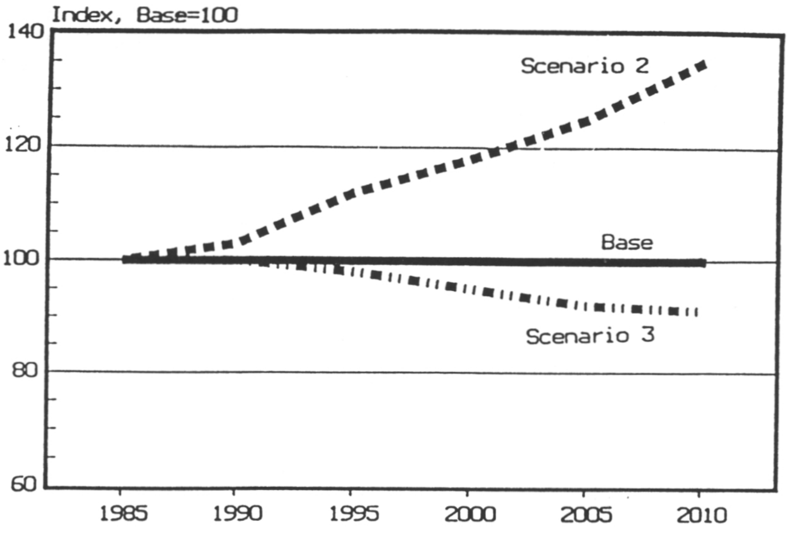

Figure 5: Total paper production in energy-policy scenarios 2 and 3 compared to the base scenario in 1985 -2010

DISCUSSION

So far, the MESTA model has been used mainly to test its structure, data base and sensitivity. We modelers have learned quite a lot, not only how to construct and modify a model, but also about the functioning of the Finnish forest sector.

Based on the model runs done up till now, we have found that there are some key factors affecting the performance and structure of the Finnish forest industry. One of the most important among these factors is the price of electricity which mainly depends on nuclear power decisions and has a major impact on the product assortment of the industry.

The degree of refinement is rapidly increasing especially in the paper industry and at the same time the industry is substituting wood with other raw materials. This means that the relative importance of wood is decreasing. In spite of this, the functioning of roundwood markets will play an essential role for the Finnish forest industries.

Even though there are several factors, such as end product markets and actions of competitors, which are beyond our control, the results show clearly that many key factors, which are under our national policy control, affect the performance of the Finnish forest industry.

A policy analysis model has not very much value if it is used only by model builders. Therefore, the next step is to involve users, i.e. to assist the planners and decision makers of the Finnish forest sector to evaluate long-term consequences of different policy options.

Planners and decision makers can be found at many levels. Our aim is to use the model mainly for two purposes: to analyze strategies of an individual forest industry company, and to study development alternatives of the whole Finnish forest sector. At present, the model is valid enough for the latter purpose but minor modifications concerning mainly global regional structure and product assortment are obviously needed to get the model to better serve the needs of a company.

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MODELING TECHNOLOGY CHANGE AND FIBER CONSUMPTION IN THE U. S. PULP AND PAPER INDUSTRY

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ABSTRACT

The U.S. Forest Service Pulpwood Model developed at the Forest Products Laboratory in Madison, Wisconsin, enables researchers to make 50-year projections of pulpwood consumption and paper and paperboard production in North America. These projections will be used by the Forest Service in its 1989 assessment of timber resources in the United States. The model incorporates changes in product and process technology identified in a survey of likely developments in pulp, paper, and paperboard industries. For each grade of paper and paperboard and for each supply region, the model determines the most cost-effective combination of technological processes and equilibrium levels of production and fiber consumption to satisfy demand. Our projections for the next 50 years show substantial growth in U.S. paper and paperboard production and increasing consumption of hardwood pulpwood. The projections also show use of a varying mix of existing and projected future technological processes in each region over time.

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[1]The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin.

INTRODUCTION

The USDA Forest Service is modeling future technological change in wood products processing in order to project more accurately the demand for timber in the United States. Results will be part of a broad assessment and detailed analysis of the demand for and supply of U.S. timber over the next five decades. This timber assessment will be completed in 1989. A similar assessment, including a detailed analysis of the timber resource, was made in 1979 (USDA 1980, 1982). The new assessment will serve as a basis for developing a program for managing U.S. national forests and research to meet future needs for wood products and other forest resources.

Since 1979, there have been major Forest Service efforts to improve methods for projecting timber consumption for various wood products. One such effort has been to develop an economic model of the pulp and paper industry--an industry that currently accounts for one-third of all annual industrial timber consumption in the United States. Another has been to determine the impact of evolving new technologies in wood products industries on future timber requirements.

A cooperative research effort with Joseph Buongiorno and Keith Gilless at the University of Wisconsin in Madison resulted in the development of PAPYRUS, a spatial equilibrium model of the North American pulp and paper industry (Gilless and Buongiorno 1987). This model provides projections of regional production, consumption, trade, prices, and fiber requirements to the year 2000.

PAPYRUS is based on a price-endogenous linear programming system (PELPS) for economic modeling of an industry sector by region and commodity (Gilless and Buongiorno 1985). PELPS uses a linear programming routine to arrive at regional equilibrium of supply and demand for a set of input and output commodities in one period of time. It then uses a set of recursive equations to update coefficients and assumptions in the linear program, enabling multi-period equilibrium solutions starting in a given base year. The database incorporates supply and demand coefficients related to price, population, and other macroeconomic variables as well as information and assumptions regarding manufacturing capacity, technology, and costs. A model based on PELPS can be used to simulate various scenarios of production activity and technology, regional differences, economic conditions, and changes over time.

A model similar to PAPYRUS was needed for the upcoming Forest Service timber assessment to project regional pulpwood and fiber consumption in the U.S. pulp and paper industry over five decades, starting in 1986. The projections needed to take into account the impact of likely changes in technology on pulpwood and fiber requirements. This required an analysis by grade of paper and paperboard.

PAPYRUS gave projections for only twenty years, starting in 1980. The model did not incorporate future technologies and, except for newsprint, projections were for broad product categories. Therefore, a new model, the Pulpwood Model, was developed at the Forest Products Laboratory in Madison, Wisconsin. It uses a modified version of PELPS as a modeling framework, including an updated (1986) data base, detailed product grades and manufacturing processes, and assumptions about future technological change (Ince et al. 1987). We are indebted to Professor Joseph Buongiorno and graduate student Patrice Calmels, at the University of Wisconsin-Madison, for teaching us how to use the PELPS system.

The objective of this paper is to describe the Pulpwood Model, highlight some preliminary projections, and discuss parts of the model needing further development.

THE PULPWOOD MODEL

The Pulpwood Model is an economic model of the present and future North American (U.S. and Canadian) pulp and paper industry (Ince et al. 1987). Its principal objective is to project regional pulpwood consumption in the United States over the next 50 years, incorporating likely changes in technology. The model also projects regional capacity and production by product grade and manufacturing process, regional wastepaper consumption, and prices of raw materials and products.

Scope and Methods

Starting with 1986 as the base year, projections are made for each decade to the year 2040 and for three U.S. regions--North, South, and West.

The model projects regional production for the following product grades:

Paper - newsprint, tissue, printing & writing, packaging & industrial

Paperboard - unbleached Kraft, solid bleached, semichemical, recycled

Construction grades - hardboard, other (construction paper, wet machine board, insulation board)

The model also projects regional consumption amounts of pulpwood and recycled fiber required for the projected levels of production. Projections of consumption are made for softwood and hardwood pulpwood and for three grades of recycled fiber: old newspapers, old corrugated containers, and other wastepaper.

For each of the above product grades, projections are made using one of two methods. For newsprint and the four paperboard grades, projections are made using a revised version of the PELPS economic modeling framework developed by Gilless and Buongiorno (1985). A regional supply-demand equilibrium is determined that defines quantities and prices for the United States and Canada for each year of the projection period. This method, our PELPS-based model, is explained in greater detail below. The five product grades included in this method are referred to as endogenous (to the PELPS-based model).

For the remaining five grades--tissue, printing & writing, packaging & industrial, and the construction grades--detailed information needed for the PELPS data base was not available. Therefore, projections are based on a separate analysis of trends and likely developments in each grade. We projected U.S. production by grade, using linear regression analysis and trend extrapolation, and distributed total production into regions based on current and projected regional capacity. We then projected regional pulpwood and recycled fiber requirements by analyzing trend data and incorporating likely technological developments in each grade. These grades are referred to as exogenous (to the PELPS-based model).

The two methods are submodels of the overall Pulpwood Model. Projections for endogenous and exogenous grades are combined to give total amounts produced and total pulpwood and recycled fiber consumed in the United States, by region to the year 2040. These totals will be incorporated into the 1989 Forest Service assessment of current and future timber resources in the United States.

PELPS-based Model

The PELPS-based model is a regional economic model of the future North American pulp and paper industry. Projections are based on a regional supply-demand equilibrium for individual grades of paper and paperboard, taking into account regional costs of production and transportation. The model projects quantities produced by region, product grade, and manufacturing process; quantities of pulpwood and recycled fiber consumed by region; and prices of all commodities in each region. As mentioned above, projections using this method are made for five product grades--newsprint and the four paperboard grades--and for a 50-year projection period, starting in 1987.

Regional market equilibrium for a particular year is found by solving a linear program describing economic and technical conditions in the industry in that year. This linear program combines a demand curve for each product grade, a supply curve for each raw material, input-output technological coefficients for each production process, transportation and manufacturing costs, and manufacturing capacities. Demand curves are a function of U.S. price, Gross National Product (GNP), and population. Supply curves for pulpwood and recycled fiber are a function of price. For pulpwood, the price elasticity is assumed to be 1.0; for recycled fiber, it is assumed to be zero but the function has an upper boundary that shifts over time depending on growth in U.S. GNP.

After the equilibrium in one year is determined, a set of recursive equations update the linear program to reflect changing endogenous and exogenous factors in the economic and technical environment of the sector. The updated linear program is then solved again, determining a new regional equilibrium for the following year. This procedure is repeated over the forecast period, giving multi-year projections.

Endogenous factors in the linear program represent conditions of the previous market equilibrium--quantities produced and consumed, capacity levels, and prices of commodities. Exogenous factors represent assumptions about input-output coefficients, new production processes, costs, initial levels and growth in capacity, and upper limits on quantities consumed. These assumptions can be changed during the forecast period.

Growth in production capacity for each grade is constrained by a distributed lag function based on changes in production levels in the previous three years. It is allocated to regions and production processes that have the lowest production costs.

We validated the model by calibrating it to actual data for 1986, our base year. This was done by making multiple runs for the base year only, testing elasticities and structural components until results coincided with actual prices and quantities of commodities produced and consumed in 1986. We assessed the feasibility of the equilibrium solutions of the model over the projection period by comparing them to historical trends and industry projections.

Modeling Technological Change

A key feature of the PELPS-based model is that it provides a method based on economic theory for projecting adoption of new technology affecting pulpwood and recycled fiber requirements in the pulp and paper industry. Thus, projected consumption of pulpwood and recycled fiber incorporates impacts of technological change.

Achieving this objective involved identifying likely future technological changes. This was a major initial phase in the development of the Pulpwood Model and, in particular, the PELPS-based model.

Following an extensive literature review and discussions with researchers and industry experts, we compiled a list of possible future developments in pulp and paper technology that could affect wood and fiber requirements (Ince 1987). This list was reviewed by various industry and technical experts. Each item was evaluated as to the likelihood of occurrence and date of commercial availability. Based on this evaluation, those developments with at least a 70 percent likelihood of occurrence during the next few decades were incorporated in future process technology for different grades of paper and board. Among these developments were the following:

1. Further displacement of chemical and groundwood pulps by modern high-yield mechanical pulps

2. Better recycled fiber recovery and more recycled fiber used in traditional virgin fiber grades

3. More use of short fiber furnish in linerboard with improved sheet forming and separate refining

For each endogenous grade, we identified one or more existing production processes that use current technology. We then identified one or more future production processes resulting from likely future technological developments. For example, we identified three existing processes and one likely future process for producing newsprint in North America:

Process 1 (Existing)--Newsprint integrated to chemical and mechanical pulp, produced using a furnish mix of approximately 25 percent bleached or semibleached chemical pulp and 75 percent mechanical pulp, typically groundwood or refiner mechanical pulp (RMP).

Process 2 (Existing)--Newsprint integrated to mechanical pulp, produced in mills using 90 to 100 percent mechanical pulp, with up to 10 percent bleached chemical market pulp.

Process 3 (Existing)--Recycled newsprint, produced in mills using up to 100 percent recycled fiber, typically old newspapers, or newsprint produced in mills that use primarily recycled furnish and small fractions of mechanical or chemical pulp.

Process 4 (Future)-- Newsprint produced using only modern high-yield mechanical pulps such as chemithermomechanical pulp (CTMP). This process will incorporate improved pressing technology, more fillers and machine finishing, more uniform product quality, and increased use of hardwood pulpwood. Wood fiber requirements and costs will be lower than for current newsprint processes.

Each current and future process is defined by specific input requirements (pulpwood and/or recycled fiber) and nonfiber manufacturing costs. These can vary by region depending on yield and cost assumptions.

In each year of the projection period, the PELPS-based model allocates growth of production capacity in each grade to the available processes and supply regions that have the lowest production costs, determined as the sum of nonfiber cost plus the cost of pulpwood and/or recycled fiber. Growth in capacity for future processes begins at specified future dates when the processes are assumed to become commercially available. Thus, for newsprint production in the U.S. North, Process 3 will become increasingly dominant, Processes 1 and 2 will decrease in importance, and Process 4 will be used to a limited extent after the year 2010 (Figure 1).

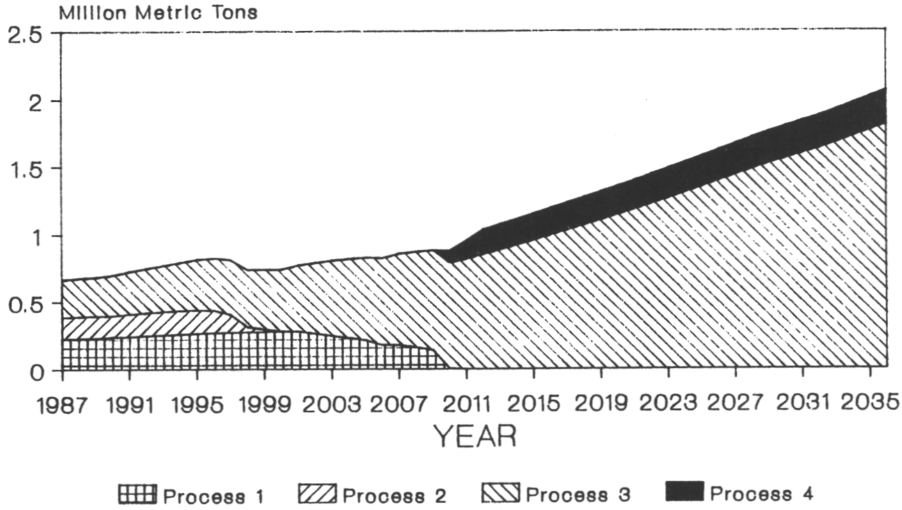

Figure 1--Projection of newsprint production in the U.S. North by production process

The PELPS-based model projects adoption of new process technology partially as a function of developing regional economic conditions. The cost of pulpwood and recycled fiber required for a given production level and process depends on regional market equilibrium prices determined by the model. If softwood remains relatively more expensive than hardwood, the model will favor adoption of processes that use more hardwood. In addition, the extremes of maximum and minimum hardwood use are defined as options for each process, so that in any period the model can switch from one extreme to the other as a matter of economic substitution within the limits of existing technology.

For the exogenous grades, as mentioned earlier, projected changes in use of pulpwood and recycled fiber are based on historical trends and assumed future developments in the use of wood pulps, substitution of recycled fiber for virgin fiber, and substitution of hardwood for softwood. This is reflected in assumptions made about changes in conversion factors over time.

Net Exports and Market Pulp

The Pulpwood Model does not include a supply-demand equilibrium for markets outside of North America (United States and Canada). In the PELPS-based model, effects of overseas trade are handled by shifting domestic demand functions for each product grade by a quantity equivalent to net overseas exports from North America. That is, in the base year, net exports are added to apparent consumption (new supply) resulting in demand on North American mills or production. Demand elasticities are unchanged. Thus, the PELPS-based model actually projects North American production of each grade of paper and paperboard, including production for export, rather than apparent consumption. For the exogenous grades, projections are also made for production, including production for export.

The Pulpwood Model also does not include a separate supply-demand equilibrium for market pulp, which is mostly integrated with paper and paperboard production. Instead, we developed assumptions regarding the interregional shipments of market pulp in North America. We adjust our initial projections of pulpwood requirements to reflect the effect of these pulp shipments.

PRELIMINARY PROJECTIONS

Our preliminary projections, developed last December, show that total U.S. paper and board production will more than double during the next 50 years, increasing from 67.1 million metric tons in 1986 to 144.8 million metric tons in the year 2040. Paper production will continue to account for about half of total U.S. production. The biggest increase is projected for the printing & writing paper grade. Production of this grade in the United States is projected to triple, from 17.8 million metric tons in 1986 to 54.1 million metric tons in the year 2040.

Newsprint production will continue to increase in both the United States and Canada. Total North American production is projected to increase by about 70 percent during the next fifty years, with U.S. production gaining an increasing share of the total.

Our preliminary projections also show that U.S. pulpwood consumption will double between 1986 and the year 2040, from 328.2 million cubic meters to 641.6 million cubic meters (Figure 2). At the same time, U.S. consumption of recycled fiber will increase even more, from 15.4 million metric tons to over 36 million metric tons. Thus, we project increasing use of recycled fiber in U.S. paper and board production.

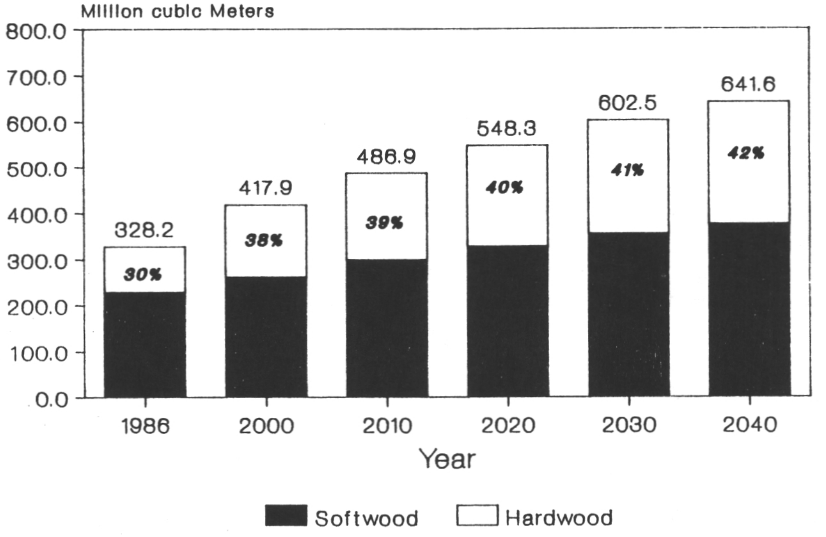

Figure 2--Projection of U.S. pulpwood consumption with an increasing proportion of hardwood.

We also project increasing use of hardwood pulpwood relative to softwood pulpwood in the United States . This has been a continuing trend in all U.S. regions, especially in the North, where the proportion of hardwood pulpwood consumption is highest and has been increasing dramatically during the last several years. Our projections show that U.S. hardwood pulpwood consumption will increase by a factor of 2.7 between 1986 and the year 2040, while softwood pulpwood consumption will increase by a factor of 1.6. The proportion of hardwood pulpwood is projected to increase from 30 percent in 1986 to 42 percent in the year 2040 (Figure 2).

These preliminary projections are subject to change in the months ahead as we make revisions in the Pulpwood Model to incorporate new data as well as comments and suggestions we received during the review process. We anticipate that our revised projections will reflect a greater shift toward use of high-yield wood pulps, hardwood pulpwood, and recycled fiber.

CONCLUSION

The Pulpwood Model developed at the Forest Products Laboratory provides long-term regional projections of production as well as consumption of pulpwood and recycled fiber in the U.S. and Canadian pulp and paper industry. These projections will be incorporated into the 1989 Forest Service assessment of future U.S. supply and demand of timber resources.

The Pulpwood Model has advantages that make it useful for various analyses and simulations of the future North American pulp and paper industry. One major advantage is that the model is a comprehensive and detailed representation of the industry. It includes all the major product grades, one or more production processes for each grade, major supply regions, and categories of pulpwood and recycled fiber. This great detail, however, requires a lot of data, which are sometimes difficult to find or are not available.

Another major advantage is that the PELPS-based model provides a method for projecting adoption of technological change in the industry and the impact of such change on consumption of pulpwood and recycled fiber.

A third advantage is that the Pulpwood Model is flexible--it can be easily and quickly changed to incorporate new data and assumptions. For example, one can add more production processes to reflect additional new technologies. Thus, one can simulate and test different future scenarios.

On the other hand, the Pulpwood Model currently has several areas that need further development. One such area involves the five exogenous grades, which currently are not included in the PELPS-based model. Projections for these grades are made using a separate analysis. Our objective is to obtain the needed data so they could also be included in the PELPS-based model, which will then represent the entire industry in the United States and Canada.

Another area in the Pulpwood Model that needs further development is the treatment of international trade and market pulp. Our objective is to develop methods and obtain the needed data to model these endogenously in the PELPS-based model.

We also need to develop a better method for determining capacity expansion in the PELPS-based model. Presently, changes in capacity are based on changes in production in prior years. An important factor that needs to be included is the amount of capital available for investment in the pulp and paper industry.

Finally, we need to develop better estimates of regional supply elasticities for pulpwood and recycled fiber used in our PELPS-based model. Currently, elasticities are assumed constant in all regions.

With these and other improvements, the Pulpwood Model will calculate long-term projections for all product grades and regions endogenously, incorporating future technologies, international trade, and market pulp.

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DETERMINANTS OF MARKET SHARES IN THE NEWSPRINT INDUSTRY

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ABSTRACT

The determinants of market shares are analysed for some countries that substantially contribute to newsprint production and sales in West Europe.

Since the market price for bulk products is set by market forces it can be expected that those units (or countries) that are efficient will expand their production capacity more than their competitors. It is therefore plausible that cost competitiveness will determine the rate of growth of capacity. This theory is, however, not obvious in the case of newsprint where the market is characterized by few sellers and buyers.

One alternative hypothesis is that 'size' is important. Those countries that already are large scale producers with efficient units tend to remain in the market and to increase their share of the total capacity in a region. Cost efficiency is here an underlying factor that indirectly influences capacity expansion due to low production costs. The indicator of 'size' is here the average capacity of the paper machines of a country.

In a market characterized by close relations between sellers and buyers with established trade channels, all changes occur only slowly, which causes inertia. This hypothesis is supported by the study.

The main emphasis in the analysis is based on a time-series cross-section model for the largest producers and sellers of newsprint in Europe.

INTRODUCTION

At the SIMS department, SLU, Uppsala, we are developing a system for forest sector analysis, which has earlier been described at a conceptual level by Lönner et. al., 1986 and Lönner 1987. The system is of a simulation type, aiming at answering typical "what-if questions", having to do with the optimal dimensioning of the Swedish forest sector. The modeling of the interdependence between forest, industry and market is focused. The system works with three main groups of scenario variables: general economic indicators, alternative demand projections, and alternative forest management programmes.

When trying to model the interdependence between the industry and market it is obvious, that a very serious bottle-neck is the lack of knowledge of the determinants of investment behavior or capacity change on the sector level. We have therefore carried out a rather basic study of this, by means of an econometric analysis of time series data. Due to large difficulties in getting reliable data on capacity change, market shares and production costs, we have so far concentrated the study to only one product as a pilot case, newsprint. This is one of the most important forest products for the Swedish forest sector, and a relatively homogenous product. We have studied only the West European market and the following producer countries: Sweden, Finland, Norway, Federal Republic of Germany, Austria, Holland, England and Canada.

Considering only the long range tendencies market shares determine capacity change. Due to practical reasons we have chosen market shares as dependent variable in the analysis.

H y p o t h e s e s

Our hypotheses when trying to explain the distribution of market shares of the main newsprint producing countries acting on the West European market can be summarized as follows:

Large actors, with a favorable industrial structure, tend to maintain or develop their market shares as long as their production costs in the long range perspective do not deviate significantly from the costs for dominating competitors on the same market. Example: Swedish producers have chosen to expand their newsprint capacity during the 1970's and 1980's more than any other country in West Europe. The reasons for this are inexpensive electricity and good supply of excellent spruce raw material The wood cost is rather high in an international comparison, but has been compensated for by means of low energy costs and a very cost efficient production structure (i.e. maximum machine size and highest technological level).

The industrial structure can, in a simple way, be expressed as the average machine size of a country. This measure does not only include the directly measurable competitive parameters, included in the production costs. It also gives an indication on the level of ambition and "intensity" for the product group. A high level of technical ambition leads to structural adaptations, aiming at best available solutions, technically and size-wise. It means high level management capacity, technically and commercially, and to confidence on behalf of the investors. Example: In spite of the decision in Sweden to close down the nuclear power with unavoidable increased energy costs as a consequence, two decided and one planned large scale capacity expansions are in the pipe-line. Qualified technicians and management have in this case handled risks for increased energy costs and local wood shortage by means of expanded use of waste paper.

It seems likely that the scale effects on production costs for this industry are very strong up to a plant size of 800-900.000 tons capacity, distributed on four machines of highest technical standard, assuming that no bottle-necks occur in the availability of capital or raw material.

Established market relations should give a rather strong inertia, so that those already in business tend to grow in proportion to the market growth, or more if possible.

Supply of capital or capital costs have not been included explicitly as explaining variables in the analysis. The reason is the strong internationalization of the capital market, which gives the effect that all investors tend to have the same capital costs wherever the investment takes place, for the countries included in the analysis.

DATA

Cost- and capacity data from the mentioned countries originate from the data bank of Jaakko Pöyry. Market and trade statistics have been collected and compiled by SIMS. Data cover the years 1970-86 and are expressed as annual averages on a country basis. Collection, check and compilation have been very time consuming, since it turned out that existing data bases were very incomplete and incorrect from the beginning.

ANALYSIS

According to the hypotheses presented above, the market share (MS) for newsprint consumption in Western Europe is a function of a vector of cost factors (C) all at constant price levels and a common currency, a size factor represented by average mill capacity (MC), a competitive index (CI), lagged market share representing inertia and an additional trend factor (t) representing other factors such as technology change etc. Since a market share by definition lies in the interval (0,1) the model should be specified so that this requirement is fulfilled. One such type of model is the logistic model, which is s-shaped in the range (0,1). By making a logit transform, ln(MS/(1-MS)), the logistic specification turns to a linear specification with the logit as dependent variable:

$$logit_{it}=A_i+B_i*C_{it}+G_i*MC_{it}+H_i*CI_{it}+K_i*t+Q_i logit_{it-1}+u_{it} \quad (1)$$

Here, index i denotes country no i and t time period t. The constants A, B, G, H, K and Q are coefficients to be estimated. This model could be estimated either directly country by country or by pooling the countries together in a combined time series cross section model. Both ways will be discussed here. The advantage of the time series cross section approach is that it may give a more general result than individual country models. On the other hand a pooled time series cross section model might not be capable of representing an individual country's behavior.

Data exist for 8 countries: Sweden, Finland, Norway, Germany, Netherlands, Austria, Canada and UK. Here, UK has been excluded from the analysis since its industrial structure has changed more dramatically than the other countries in the observation period. The observation period is from 1970 to and including 1986.

First, let us define the competitive index. It is believed that capacity expansion is the result of an evaluation of the behavior of closest 'competitors' on the market. Those who have an advantage in cost terms over the nearest competitive countries are those who are most likely to make capacity expansions (in terms of increased market share or capacity share). Here, we define the ratio between total cost (TC) for two competing countries (or regions) as the competitive index. For Sweden, the ratio is TCFIN/TCSWE, that is the total production cost per ton of newsprint in Finland divided by the total cost of production per ton of newsprint in Sweden. The corresponding measure for Finland is TCSWE/TCFIN. It is believed that, as the ratio increases, the market share will increase. For Norway, the ratio is TCSWE/TCNOR and for the other countries it is defined as TCEUR/TCi, where TCEUR is an average total cost per ton of newsprint for Europe and i represents total cost for country i under investigation.

For the time series cross section approach it is believed that the effect of the competitive index should be seen as individual country variables, which means that we define a variable that contains the ratio TCFIN/TCSWE for Sweden and zero for all other countries. Competitive indexes for the other countries are defined analogously. There is no doubt that this variable also is a cross sectional variable, obviously related to a country specific dummy variable that might operate as an individual country intercept. Because of the high correlation between country dummy variables and CI both cannot enter the model simultaneously.

The estimates of the time series cross section approach is given in Table 1.

Table 1. Estimated coefficients of (1): The time series cross section approach.

Dependent variable: Logit of market share

Variable	Coefficient	t-value
MC	.0032326	5.60
CISWE	1.54946	38.10
CIFIN	2.17039	36.36
CINOR	1.05679	22.16
CIGER	1.02131	23.29
CICAN	1.28970	25.89
CAND85	-.4409	-3.88

Residual standard error = se = .1527

R^2 = .964   number of observations = 119

It should be noticed that all cost factors are dropped since they are insignificant variables as well as some of the individual countries' competitive indices; indices for Sweden, Finland, Norway, Germany and Canada are included. In this model a dummy is included for the extreme year 1985 for Canada (CAND85), which otherwise would have had a large impact on the estimates.

The lagged logit variable was significant and contributed to improve the R^2 somewhat, but the long term coefficients that were calculated were almost identical to the corresponding coefficients in Table 1. Therefore, for long term purposes, little is gained by introducing a lagged dependent variable. Furthermore, when the model was evaluated it was found that the estimated market shares 'lagged' when compared to the observed market shares. This is, of course, an effect of a rigid behavior of the lagged term.

An important factor here is the size factor (MC) which demonstrates that those who are large want to stay in the business and to expand further.

The t-values of the competitive indices are large but should, as mentioned above, to a large extent be explained by the cross sectional effect; the variable explains not only competitive factors but also cross sectional differences between countries.

The model fit is presented in Figures 1-7, where observed and estimated market shares are compared.

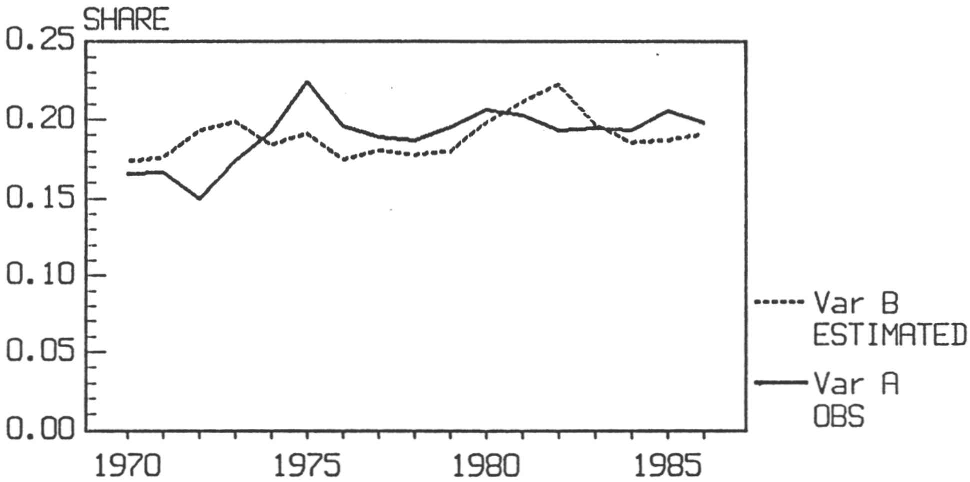

Figure 1. Sweden - observed and estimated market shares of newsprint in West Europe.

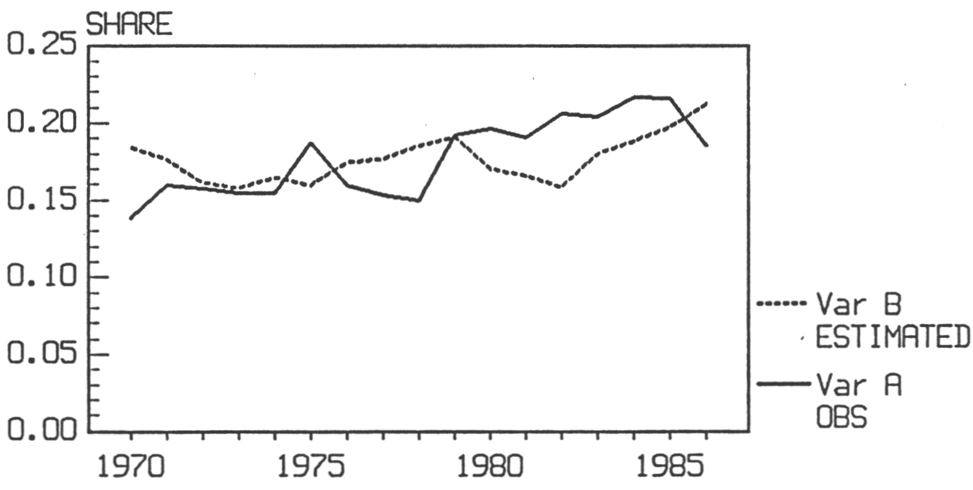

Figure 2. Finland - observed and estimated market shares of newsprint in West Europe.

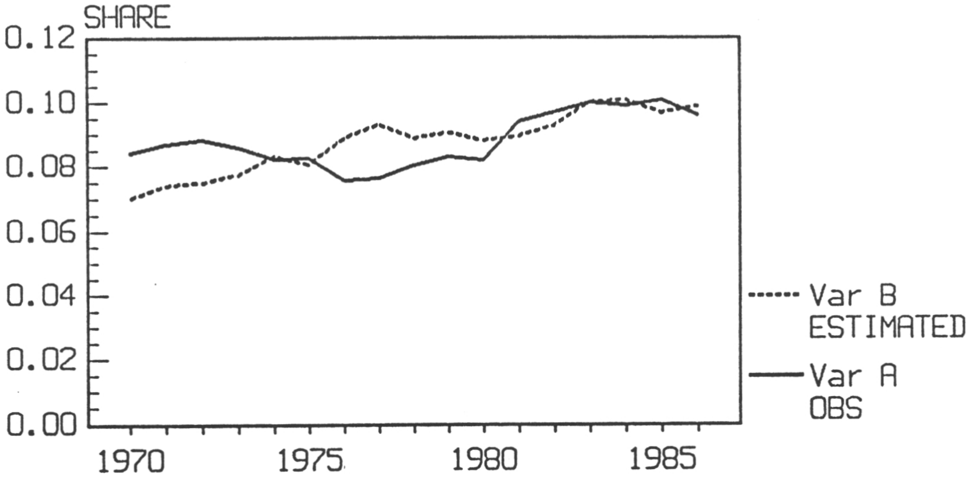

Figure 3. Norway - observed and estimated market shares of newsprint in West Europe.

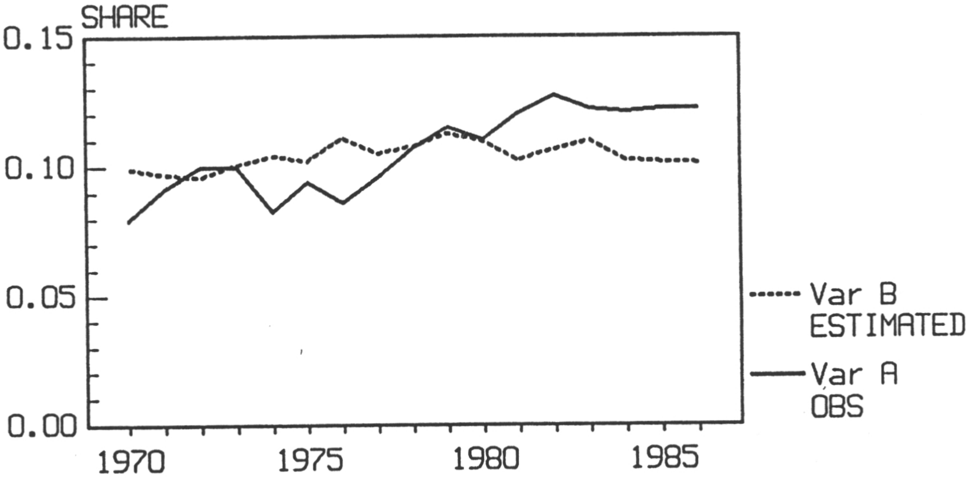

Figure 4. Germany - observed and estimated market shares of newsprint in West Europe.

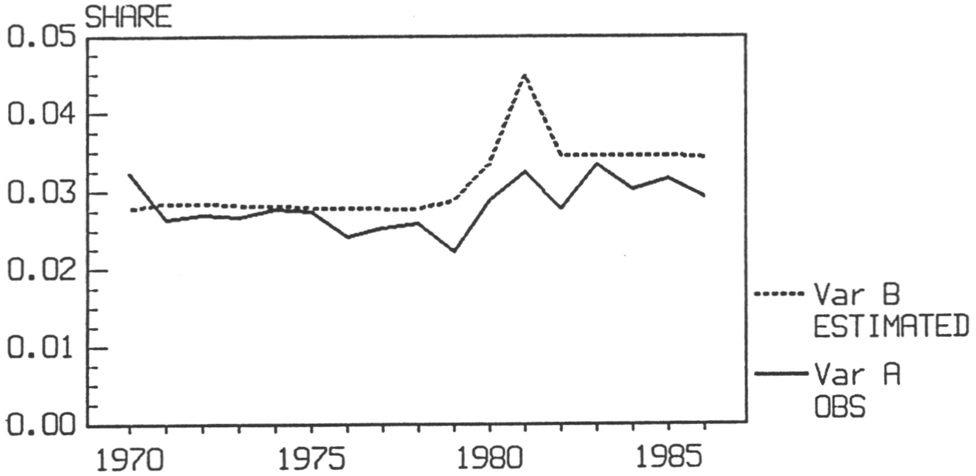

Figure 5. Netherlands - observed and estimated market shares of newsprint in West Europe.

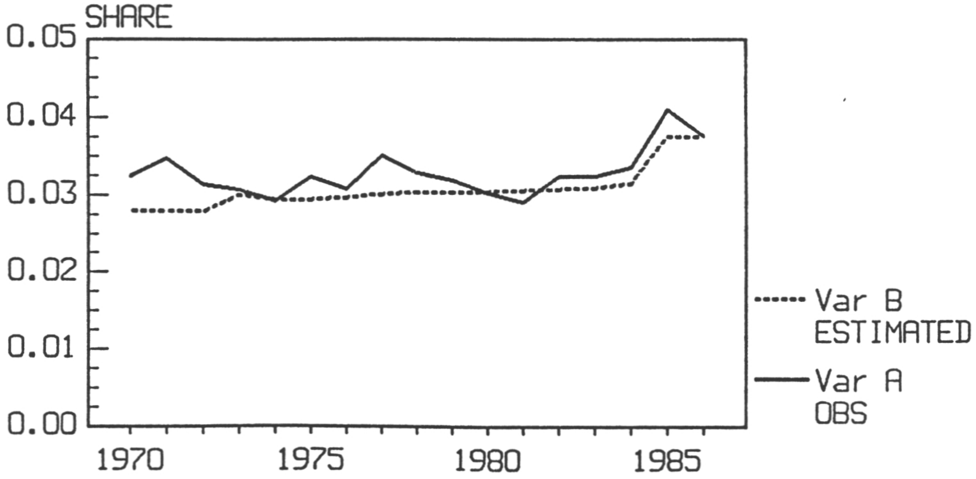

Figure 6. Austria - observed and estimated market shares of newsprint in West Europe.

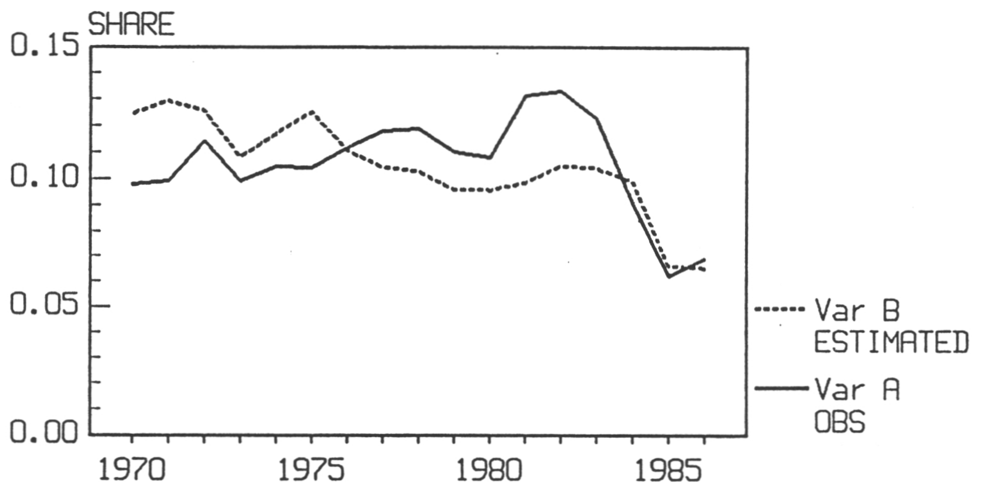

Figure 7. Canada - observed and estimated market shares of newsprint in West Europe.

The other way of estimating model (1) would be to carry out the analysis country by country, however, with a small number of observations and less generally valid conclusions. From that analysis very different results emerge. The results are summarized in Table 2.

Table 2. Estimates of model (1) using data for individual countries.

Dependent variable: logit of market share

	Variable	coefficient	t-value
SWEDEN:			
	CM	.004791	3.63
	FiberC	.001162	4.76
	TransportC	.0004875	2.65
	CI	.3692	1.17
	Logitt-1	-.4881	-1.82

$R2$ = .763 standard error of residuals = se =.0556

(Table 2 cont.)

FINLAND:

CM	.005519	2.39
LabourC	.003178	4.93
CI	-1.0669	-1.28

R2 = .60 se = .1113

NORWAY:

CM	.003978	2.57
FiberC	-.000259	-2.24
EnergyC	.000725	2.38
LabourC	-.001751	-4.03

R2 = .778 se = .0484

GERMANY:

CM	.002189	1.61
CI	-1.3544	-2.51

R2 = .738 se = .0873

NETHERLANDS:

logitt-1	-.3033	-1.26
EnergyC	-.00032	-1.43
LabourC	-.00245	-3.41
CI	-.6884	-1.61
t	.00965	1.54

R2 = .57 se = .0722

AUSTRIA:

LabourC	-.001584	-3.52
TransportC	-.000444	-2.77
t	.008144	2.84

R2 = .61 se = .0568

CANADA:

TransportC	-.000258	-1.34
CI	-.7805	-1.96
CAND85	-.6783	-6.62

R2 = .74 se = .1140

The size factor (CM) seems to be the most important variable for most countries, even if it for some countries is not significant (Canada, Netherlands and Austria). The results obviously differ substantially between countries. For some countries certain cost factors are important while for other countries the size factor dominates. The small number of observations makes it hard to make definite conclusions from this part of the analysis.

Here, we find that the competitive index is not important in most cases. For some countries it even gets a sign that is not a priori expected (Finland, Netherlands, Canada). One can thus conclude that – as an instrument for prediction purposes – the time series cross section model results for CI may work while as an explanation for individual countries' behavior it is less successful.

The results in terms of observed and estimated market shares are presented in Figures 8–14.

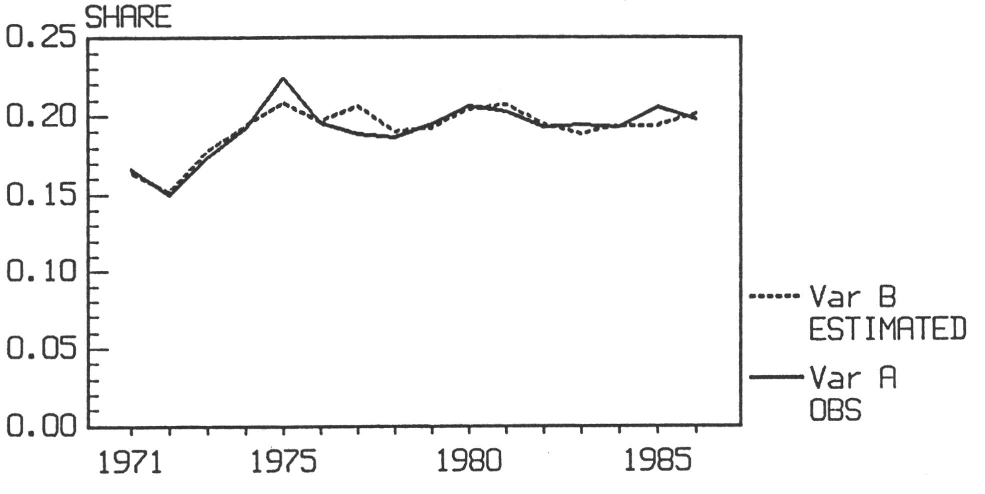

Figure 8. Sweden – observed and estimated market shares of newsprint in West Europe. The individual country's approach.

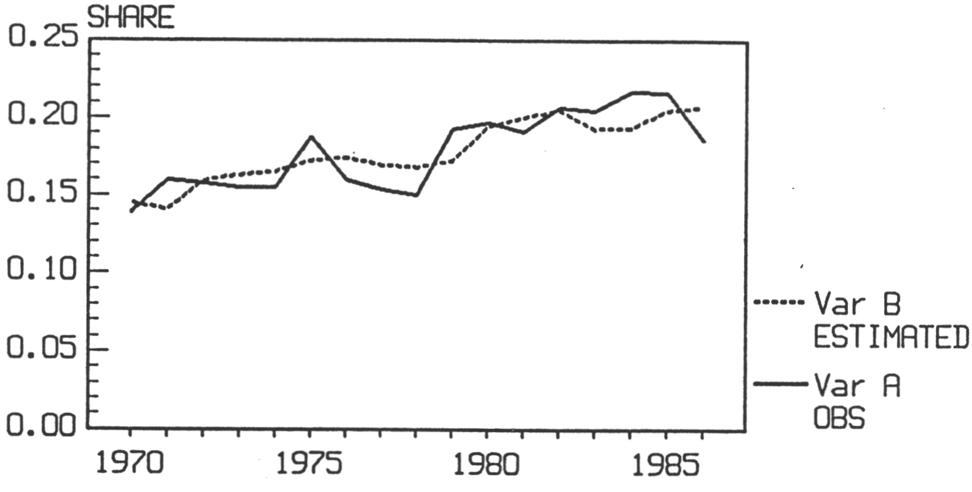

Figure 9. Finland - observed and estimated market shares of newsprint in West Europe. The individual country's approach.

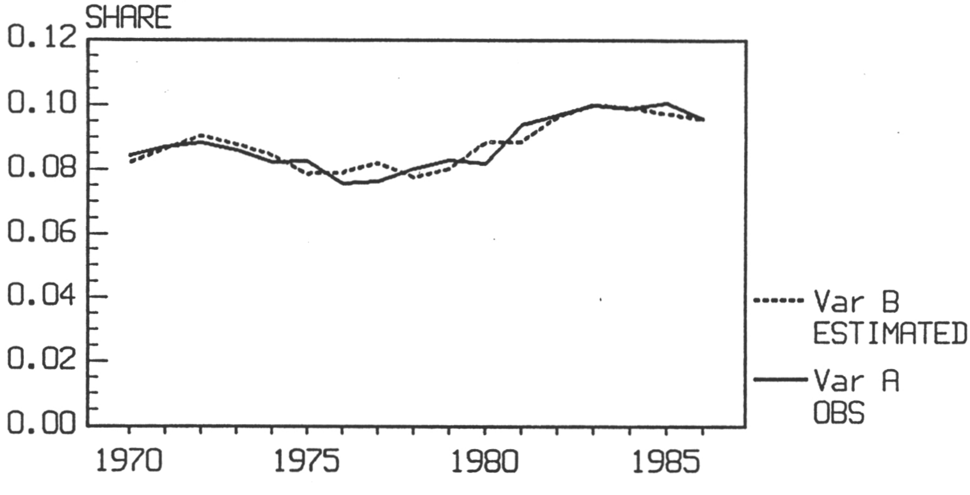

Figure 10. Norway - observed and estimated market shares of newsprint in West Europe. The individual country's approach.

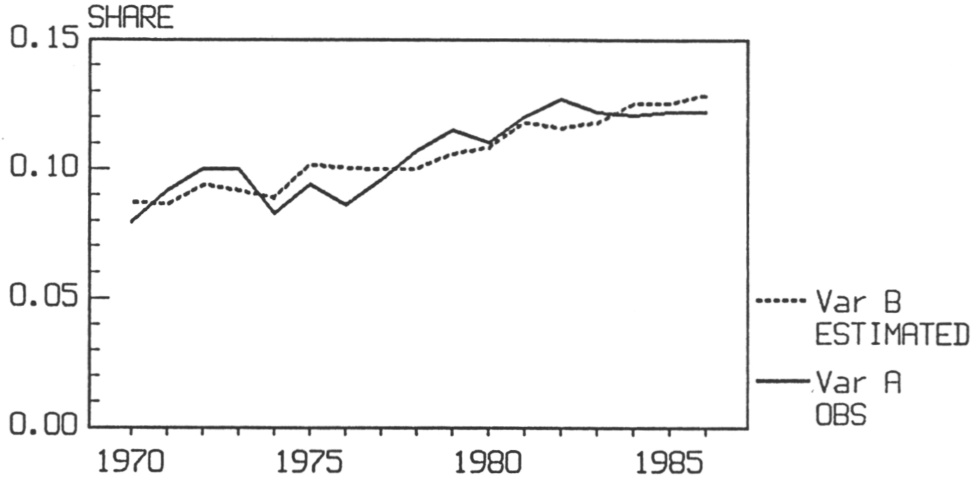

Figure 11. Germany - observed and estimated market shares of newsprint in West Europe. The individual country's approach.

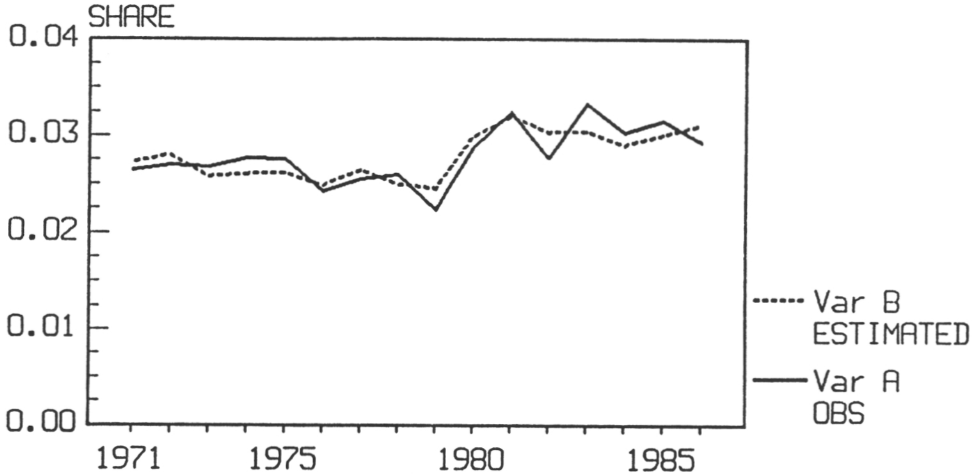

Figure 12. Netherlands - observed and estimated market shares of newsprint in West Europe. The individual country's approach.

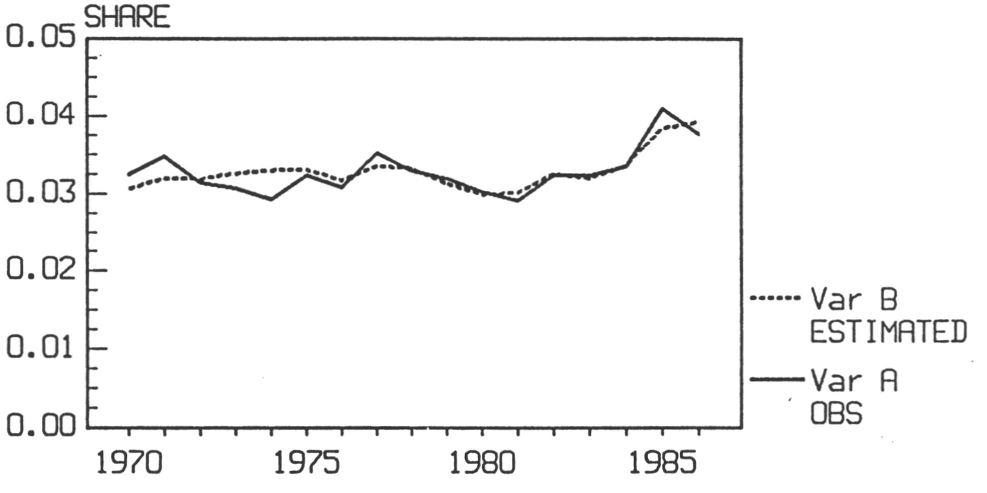

Figure 13. Austria - observed and estimated market shares of newsprint in West Europe. The individual country's approach.

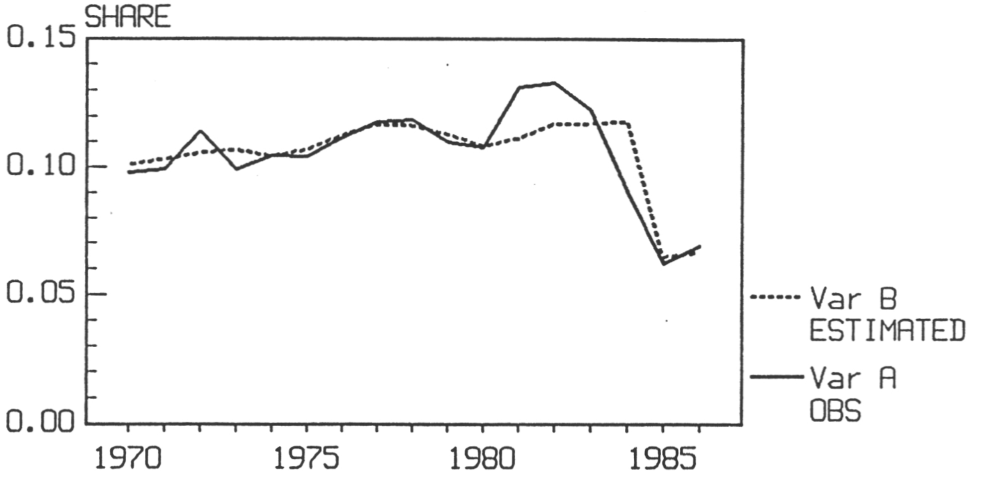

Figure 14. Canada - observed and estimated market shares of newsprint in West Europe. The individual country's approach.

The model fit is better for the individual models approach than for the pooled time series cross section approach which is not surprising when the different behavior among countries is considered.

CONCLUSIONS

It is obvious that explicit cost factors are not dominating the market position. This study emphasizes the importance of size - those who are big in the business tend to stay on the market and also try to expand their share. Even if we do not use the dynamic version of (1) we found that lagged logit was an important factor which means that the market is characterized by inertia. Those who are in the market tend to remain so. The impact of cost competitiveness is rather small and varies considerably among countries.

Still, it is obvious that the position in relation to the main competitors has an impact on the investment decisions. Our explanation to the results are, that size determines the basic decision to make the investment, while the relative competitiveness determines the timing.

Our conclusion for the choice of model to be included in our forest sector system is that the time series cross section approach seems to give a more generally valid model. For prediction purposes this model reacts adequately on the general economic indicators that will be used as scenario variables.

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METSO -

FOREST INCOME CALCULATION SYSTEM

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University of Joensuu

METSO is a micro computer program for assistance in financial planning for private forest owner. The program has been developed as a Master's thesis in forest management planning in the University of Joensuu.

The name METSO is an abbreviation from Finnish word "metsätulolaskelma" (calculation of forest income). METSO is also a grand gallinaceous bird, in English a wood grouse, which can be found in old pine and spruce forests.

METSO pays attention to personal desires and needs of forest owner and to forest's natural production capacity. An ordinary forest management plan and its information is used as a primary data for METSO. A forest management plan can also be brought up to date by METSO.

METSO uses the same forest growth models as the MELA-system. METSO grows the forest first from the moment of elaboration of forest management plan until nowadays, based on the data of each compartment. Thereafter the growing is then continued to the future. METSO calculates the forest income for the next then year period and draws up different investment calculations.

With graphs and tables the forest management plan can be presented in a more interesting way. The outputs of METSO are:

- summarized information of the whole forest holding
- particular information of each compartment
- forest income for the next ten year period
- alternative investment calculations.

METSO is in use in Skopbank Grop and in local forestry societies all over Finland. Forest experts use the system as a tool in counselling private forest owners. The most useful situations for the utilisation of program are for example:

- transfer of a farm to a descendant
- farmtrade
- choosing an alternative branch of production
- productional planning
- financial planning
- investment planning.

APPENDIX

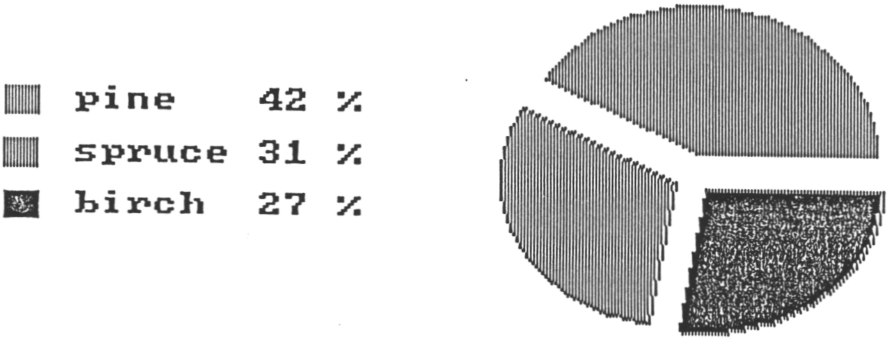
SUMMARY FROM WHOLE HOLDING

Owner : UKKO METSO   Area : 24.2 he

Mark	Total	Per hectare	
Volume, p	1840	76.1	m3
Volume, sp	1359	56.2	m3
Volume, b	1205	49.8	m3
Volume, tot.	4405	182.0	m3
Timber tree, p	1276	52.7	m3
Timber tree, sp	582	24.1	m3
Timber tree, b	403	16.7	m3
Timber tree, tot.	2261	93.4	m3
Pulp wood, p	459	18.9	m3
Pulp wood, sp	706	29.2	m3
Pulp wood, b	647	26.8	m3
Pulp wood, tot.	1812	74.9	m3
Incre, p	70	2.9	m3
Incre, sp	68	2.8	m3
Incre, b	53	2.2	m3
Incre, tot.	191	7.9	m3
Value, p	303660	12547.9	mk
Value, sp	160934	6650.2	mk
Value, b	103479	4276.0	mk
Value, tot.	568073	23474.1	mk
Value incre, p	13179	544.6	mk
Value incre, sp	9989	412.8	mk
Value incre,b	5190	214.4	mk
Value incre,tot.	28358	1171.8	mk

Information by species   WHOLE HOLDING

VOLUME   4404 m3



CALCULATION FOR FOREST INCOME FOR PERIOD OF 10 YEARS ON THE

BASIS OF FELLING FORECAST OF MANAGEMENT PLAN 1987 - 1996

* THINNED

Cnu	Inter.	psaw	spsaw	bsaw	ppulp	sppulp	bpulp	st.pri	de.pri	costs
3	7.8	0	124	25	0	109	188	43863	74786	0
4	10.3	0	0	42	0	0	144	14503	29447	0

* REGENERATED

Cnu	Inter.	psaw	spsaw	bsaw	ppulp	sppulp	bpulp	st.pri	de.pri	costs
6	1.6	241	102	229	28	53	152	121802	167601	11900
1	2.0	317	312	182	71	237	140	183658	253776	17500
2	2.7	294	8	2	79	14	18	71471	90480	9240
TOTAL		852	546	480	178	414	642	435300	616100	38600

==> AVERAGE NET INCOME FROM WOOD SALES

ON STUMPAGE SALE 39700 mk/year

SALE AT DELIVERED PRICE 57700 mk/year

When selling the wood visit your local forestry society:

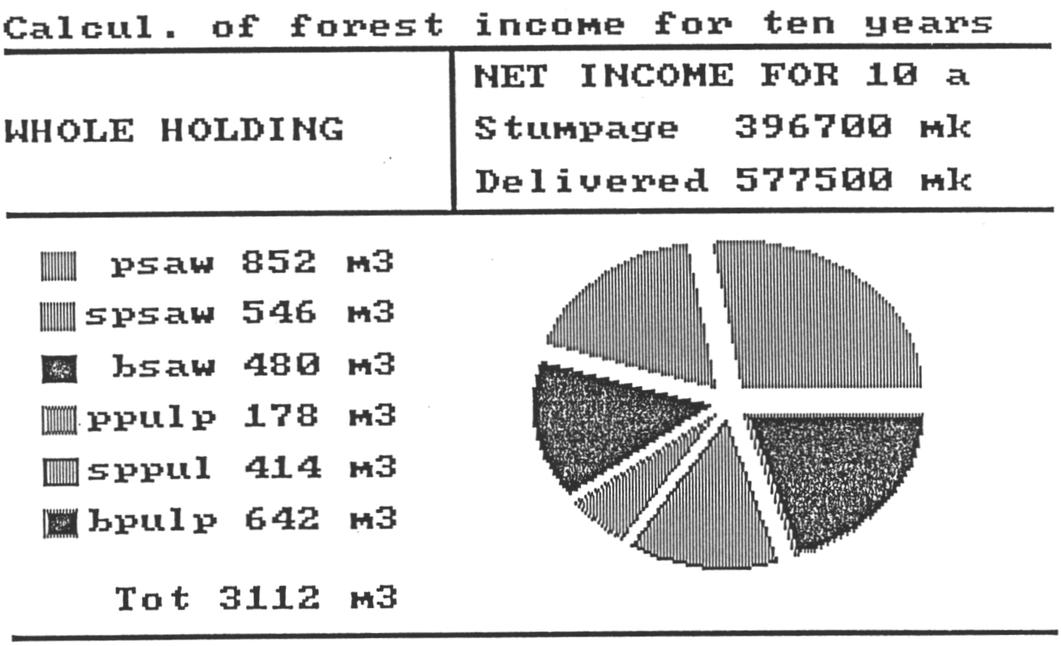
Kiteen mhy
Olkontie 6
82500 Kitee

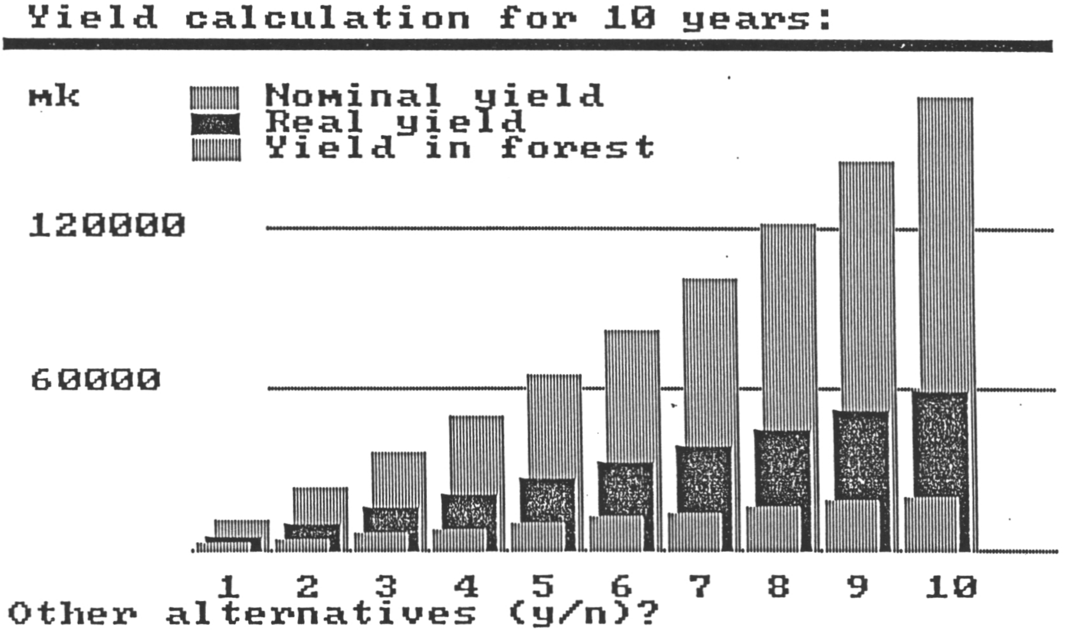
Puh 973-413236

Have always a connection with your local forestry society

when determining the felling succession and time.

Ask always the forest expert"s opinion !




Yield calculation for 10 years:
mk
Nominal yield
Real yield
Yield in forest
120000
60000
1 2 3 4 5 6 7 8 9 10
Other alternatives (y/n)?

EXPECTED PRICES AND THE FELLING DECISION

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ABSTRACT

A model is proposed that describes felling behaviour in NIPFs as a function of expected prices. The model is developed and it is shown that the correlation structure of timber prices that results may or may not exhibit randomness depending on the nature of the market and expectation formation mechnism. It is argued that, if expectations are rational, timber prices may be serially correlated but forest owners will not be able to increase profitability by the application of simple rules of thumb. Japanese data are used to show that timber prices in the study period were not random but that knowledge of the lack of randomness could not have been used to increase the profits from forestry. It is concluded that the Japanese market may, therefore, exhibit rational expectations.

INTRODUCTION

The decision to fell a stand of timber is based, at least in part, on the timber prices that the forest owner expects to rule in the future. Here, a model of the felling decision based on such a rationale will be suggested and the effect that such behaviour has on the pattern of prices discussed.

THE MODEL OF THE FELLING DECISION

Consider a forest owner who manages a small stand of even-aged timber. In determining the optimum time to fell imagine that the owner considers a series of timber prices that are expected to rule in each future period, n. From this path of expected prices a related path of expected net present values can be defined by Equation 1.

$$ {}_tNPV_{t+n} = \frac{{}_tP_{t+n}V(T+n) + F}{(1+r)^n} \qquad n=1,2,... \qquad (1) $$

Here ${}_tNPV_{t+n}$ = the expected net present value per hectare derived from felling the stand in period **t+n**, the expectation being formed in the current period, **t**,

${}_tP_{t+n}$ = the price per cubic metre expected in period t+n, the expectation being formed in the current period, **t**,

T = the age of the growing stock of the forest owner in question,

V(T+n) = the volume of timber per hectare after n periods,

F = the value of an infinite number of rotations beginning immediately after felling the present stand, deemed to be constant, and

r = a discount rate with suitable risk premium.

Let the time period **in the future** that coincides with the maximum value for the expected net present value be **m**. The forest owner will fell the timber in the current period if the inequality in 2 is true.

$$ P_tV(T) + F > \frac{{}_tP_{t+m}V(T+m) + F}{(1+r)^m} \qquad (2) $$

Here P_t = the price per cubic metre in the current period, t. It will be assumed that this is known with certainty.

A **critical price expectation,** ${}_tP_{t+m,c}$, can be calculated that renders the inequality in 2 into an equality. Given this price expectation the forest owner would be indifferent between felling in the current period and allowing the forest to continue to stand. This **critical price expectation** is given by Equation 3.

$$ {}_tP_{t+m,c} = \frac{(1+r)^m(P_tV(T)+F)-F}{V(T+m)} \qquad (3) $$

If the forest owner's price expectation in period **m** exceeds this **critical price expectation** the forest owner will not fell the stand in the current period, if it is less than this value the forest owner will.

A MODEL OF THE MARKET

Consider the group who own forests aged **T** and believe the maximum net present value in the future to occur in period **m**. Assume that the forest owners who fall into this group have price expectations that are distributed according to the function $f({}_tP_{t+m})$ with a mean value of ${}_tPM_{t+m}$. The supply of timber from this group will be given by Equation 4.

$$S_{T,m} = N_{T,m}AV(T) \int_{-infinity}^{{}_tP_{t+m,c}} f({}_tP_{t+m})dP \qquad (4)$$

Here $S_{T,m}$ = the supply of timber from age class **T** from those forest owners who believe the maximum future expected net present value will occur in period **m**,

$N_{T,m}$ = the number of forest owners in the group in question,

A = the average area held by an individual forest owner.

In the context of Japan, forestry often represents a part of the activities of a farming family. Thus, if the family is heavily engaged in its primary agricultural activities it will not have the time or resources to consider its investment in forestry. The variable $N_{T,m}$, therefore, represents those owners who are currently **actively considering selling stumpage or felling their timber.**

The proportion of an individual group of forest owners that will fell their timber varies directly with current price and inversely with the mean expected price in the future periods. A linear form of this relationship is given in Equation 5.

$$S_{T,m} = (a+bP_t+c_tPM_{t+m}+\delta_{T,m,t})(N_{T,m}V(T)A) \quad b>0,c<0 \quad (5)$$

Here $\delta_{T,m,t}$ = the deviation from this general proportion in period t for the **Tth** age group and the group of owners whose maximum net present value occurs in period **t+m**.

Define the following relationship.

$$N_{T,m}V(T)A = K + \beta_{T,m,t} \qquad (6)$$

Here K = the average standing volume in each age class and NPV maximisation groups which the owners are actively considering felling, and

$\beta_{T,m,t}$ = the deviation from this average in period t for the **Tth** age class and the group of owners whose maximum net present value occurs in **m**.

If there are **z** age clases and **M**, a finite number, represents the greatest value for **m** the total supply in period **t**, S_t, is given by Equation 7.

$$S_t = \sum_{T=1}^{z} \sum_{m=1}^{M} (a+bP_t+c_tPM_{t+m}+\delta_{T,m,t})(K+\beta_{T,m,t}) \qquad (7)$$

If the definitions in Equations 8 to 13 are made, and if the errors

$\delta_{T,m,t}$ and $\beta_{T,m,t}$ are not correlated with each other relationship and $\beta_{T,m,t}$ is uncorrelated with ${}_tPM_{T,m}$ Equation 7 can be rewritten as Equation 14.

$$A = zMa \quad > \text{ or } < 0 \qquad (8)$$

$$B = zMb \quad > 0 \qquad (9)$$

$$C = zMc \quad < 0 \qquad (10)$$

$${}_tPM = \frac{1}{zM} \sum_{T=1}^{z} \sum_{m=1}^{M} {}_tPM_{t+m} \qquad (11)$$

$$\delta_t = \frac{1}{zM} \sum_{T=1}^{z} \sum_{m=1}^{M} \delta_{T,m,t} \qquad (12)$$

$$\beta_t = \frac{1}{zM} \sum_{T=1}^{z} \sum_{m=1}^{M} \beta_{T,m,t} \qquad (13)$$

$$S_t = (A + BP_t + C_tPM + \delta_t)(K + \beta_t) \qquad (14)$$

A simple linear demand model for timber will be assumed. Demand depends on current price and an error term y as shown in Equation 15.

$$D_t = G + HP_t + y_t \qquad G > 0,\ H < 0 \qquad (15)$$

The Error Terms

Three error terms are included in the supply and demand functions, the correlation structure of which can take any form. Consider, for example, y_t, the error terms in the demand function. These might be serially independent random variables. This would represent shocks to demand that persisted for one period only. Alternatively they might be "persistent" but serially independent. In this case they would represent shocks that altered the position of the demand function permanently. Again the errors might be serially correlated. In both cases the persistence of the effect would be reflected in the order of the serial correlation. Following Muth (1961) to model different error structures define of the error terms by Equations 16, 17 and 18.

$$\delta_t = \sum_{i=0}^{\text{infinity}} u_i \alpha_{t-i} \qquad Exp(\alpha_j)=0;\ Exp(\alpha_i \alpha_j)=\sigma^2_\alpha \text{ if } i=j;\ Exp(\alpha_i \alpha_j)=0 \text{ if } i<>j \qquad (16)$$

$$\beta_t = \sum_{i=0}^{\text{infinity}} v_i \gamma_{t-i} \qquad Exp(\gamma_j)=0;\ Exp(\gamma_i \gamma_j)=\sigma^2_\gamma \text{ if } i=j;\ Exp(\gamma_i \gamma_j)=0 \text{ if } i<>j \qquad (17)$$

$$y_t = \sum_{i=0}^{\text{infinity}} w_i \phi_{t-i} \qquad Exp(\phi_j)=0;\ Exp(\phi_i \phi_j)=\sigma^2_\phi \text{ if } i=j;\ Exp(\phi_i \phi_j)=0 \text{ if } i<>j \qquad (18)$$

Any desired error structure can be obtained by an appropriate choice of the weights, u_i, v_i and w_i. Using the errors in demand, y_t as an example, Table 1 shows the assumptions concerning the weights w_i to model the different types of error that will be discussed here.

TABLE ONE

ERROR STRUCTURES

Type of error in demand	Required values for w_i
Independent, transient	$w_0 = 1$ $w_1 = w_2 = \ldots = 0$
Serially correlated, transient	$w_0 = 1$ $0 < w_1 < 1$ $w_2 = w_3 = \ldots = 0$
Independent, persistent	$w_0 = w_1 = \ldots = 1$
Serially correlated, rapidly incorporated persistent	$0 < w_0 < 1$ $w_1 = w_2 = \ldots = 1$
Serially correlated, slowly incorporated persistent	$0 < w_0 < 1$ $w_0 < w_1 < 1$ $w_2 = w_3 = \ldots = 1$

The Complete Market Model

The complete model of the timber market can now be represented by Equations 19, 20 and 21.

$$S_t = (A+BP_t+C_tPM+\sum_i u_i\alpha_{t-i})(K+\sum_i v_i\gamma_{t-i}) \qquad (19)$$

$$D_t = G+HP_t+\sum_i w_i\phi_{t-i} \qquad (20)$$

$$S_t = D_t \qquad (21)$$

EXPECTATION FORMATION MECHANISMS AND TIMBER PRICES

Different mechanisms of price expectation formation and types of error struture will be suggested and the path of timber prices that they induce will be found. The mechanisms to be discussed are as follows;

a. Naive expectations
b. Simple error learning expectations
c. Individual error learning expectations
d. Rational expectations
e. Distributed rational expectations

Only the prices differences between periods t and t+1, and periods t+1 and t+2 will be examined. To this end the notation in Equations 22 and 23 will be used.

$$DP_t = P_{t+1} - P_t \qquad (22)$$

$$DP_{t+1} = P_{t+2} - P_{t+1} \qquad (23)$$

Naive Expectations

In this model all forest owners expect the price in all periods to be constant but each individual forest owner has an individual expectation given in Equation 24.

$$_tP_{t+n} = P_t + e_f \quad \text{for all } n > 0 \qquad (24)$$

It is convenient, but not critical, to assume that e_f, a forecasting error, is symmetrically distributed about zero. The average expected price for all groups of forest owners for all periods will be the current price, i.e. $_tPM$ equals P_t. This gives rise to the supply function in Equation 25.

$$S_t = (A+(B+C)P_t+\sum_i u_i\alpha_{t-i})(K+\sum_i v_i\gamma_{t-i}) \qquad (25)$$

Under this assumption any group owning forests of a given age will face a type of Faustmann net present value function with a maximum at period **m**. All forest owners in an age group will either fell their forests or not according to whether their net present value functions reach their maximums in the current period. Thus, the values for $S_{T,m}$ in Equation 4 will be either $N_{T,m}V(T)A$ or zero.

The price of timber in any future period is given by Equation 26.

$$P_{t+n} = \frac{(A+\sum_i u_i\alpha_{t-i+n})(K+\sum_i v_i\gamma_{t-i+n})-G-\sum_i w_i\Phi_{t-i+n}}{H-(B+C)(K+\sum_i v_i\gamma_{t-i+n})} \qquad (26)$$

The Error in Demand

Different structures in the error terms α, γ and Φ will lead to different patterns in the price differences PD_t and PD_{t+1}. To illustrate this consider the error terms in demand, $w_i\Phi_{t-i}$. Assume that the errors $u_i\alpha_{t-i}$ and $v_i\gamma_{t-i}$ are independent and transient. The denominator of the right-hand side of Equation 26 becomes an independent random variables with an expected value of

(**H-BK-CK**) and a variance related to the variance of γ. For clarity denote the denominator as **Den** and a standard deviation of σ.

Consider the effect of the error in demand in period **t** on price differences. These effects are given by Equations 27 and 28.

$$\frac{dPD_t}{d\Phi_t} = -\frac{w_1}{Den} + \frac{w_0}{Den} \quad (27)$$

$$\frac{dPD_{t+1}}{d\Phi_t} = -\frac{w_2}{Den} + \frac{w_1}{Den} \quad (28)$$

Making the assumption that the variance of **Den** is small compared to its expected value the expected values of these differentials can be approximated by Equations 29 and 30.

$$Exp\left(\frac{dPD_t}{d\Phi_t}\right) = (w_0 - w_1)\frac{1}{Den}\left(1 + \frac{\sigma^2}{Den^2}\right) \quad (29)$$

$$Exp\left(\frac{dPD_{t+1}}{d\Phi_t}\right) = (w_1 - w_2)\frac{1}{Den}\left(1 + \frac{\sigma^2}{Den^2}\right) \quad (30)$$

The expression given by Equation 31 results.

$$PD_{t+1} = \frac{(w_1-w_2)}{(w_0-w_1)} PD_t \quad (31)$$

If the errors are independent and transient no relationship will emerge. Any random shock in demand will immediately effect current price and expectations. The expected effect in periods **t+1** and **t+2** will be zero. Thus, the expected value of PD_t will be equal to the movement of price as its returns, in one period, to "normal". The expected value of PD_{t+1} will be zero.

However, if transient errors exhibit first-order serial correlation a relationship between subsequent price differences emerges. A "positive" error in demand instantaneously raises price. This error is associated with a smaller positive error of in the next period so price falls and then, in the subsequent period, is expected to fall again to its "normal" level. In this way, price differences will be correlated, the correlation being related to the correlation coefficient between errors.

Independent and persistent errors lead to no expected relationship between successive differences in price. Price moves instantaneously to its new level and is expected to remain there. The expected value for both PD_t and PD_{t+1} are zero. If the persistent error requires two periods to take full effect, again, no relationship emerges. The error in period **t** is entirely incorporated into the demand curve by period **t+1**. Thus, PD_{t+1} will have an expected value of zero.

However, if the shock takes longer to be incorporated into demand Equation 32 shows that a relationship between successive price difference will be established. The expected values of PD_t and PD_{t+1} will be of the same sign.

The results of the analysis are summarised in Table 2. A similar table can be drawn up if errors in the supply function are considered.

TABLE TWO

THE CORRELATION STRUCTURE OF PRICE DIFFERENCE

	Serial correlation of PD_t and PD_{t+1} for different models		
Error type	Naive	Error learning	Rational
Independent, transient	none	positive	none
Serially correlated, transient	positive	positive	positive
Independent, persistent	none	positive	none
Serially correlated, rapidly incorporated, persistent	none	positive	none
Serially correlated, slowly incorporated, persistent	positive	positive	positive

Simple Error Learning Model

Assume that forest owners have an idea of the "normal" price of timber in the market and that they modify this assumption when new information in the form of the latest market price becomes available. An equation such as 32 will describe this process (Nerlove, 1956). ${}_{t-1}P_{t+n}$ represents the price that was expected for all future periods, the expectation being formed in the previous period. This new price forecast is, likewise, assumed to rule for all periods in the future. Thus, ${}_tPM$ will equal ${}_tP_{t+n}$ and ${}_{t-1}PM$ will equal ${}_{t-1}P_{t+n}$.

$${}_tP_{t+n}={}_{t-1}P_{t+n}+q(P_t-{}_{t-1}P_{t+n}) \quad 0<q<1 \qquad n=1,2.... \quad (32)$$

This expectation mechanism gives the following price function.

$$P_t=\frac{(A+(C(1-q)_{t-1}PM+\sum_i u_i\alpha_{t-i})(K+\sum_i v_i\gamma_{t-i})-G-\sum_i w_i\Phi_{t-i}}{H-(B+Cq)(K+\sum_i v_i\gamma_{t-i})} \qquad (33)$$

Because the price of timber in period t depend on the expectation in the previous period, which in turn, depends on the previous price P_{t-1}, it follows that the current price will be related to the previous price. Thus, even if errors are independent, the expectation mechanism will build a degree of serial correlation into the timber price series. The relationships generated by this mechanism are showm in Table 2.

Individual Error Learning Model

Here every individual forest owner expects price to evolve in a unique path. The path of expected timber prices through time might be modified in the way implied by Equation 32 or in a less restrictive way. For example, the correction applied to the expected price in period t+n might related to n so that prices in the distant future are subject to less adjustment. In this situation the critical period m for a forest owner might well change and with it the aggregate $_tPM$. It is concievable that an increase in current price, by altering m for each forest owner, might result in a reduction in $_tPM$.

However, in general, we can expect the results in Table 2 to hold.

Rational Expectations

Under the assumption of rational expectations forest owners are thought to understand the market in which they operate. Thus, the expected price for a period in the future becomes equal to the actual price that will rule in the market at that time. This is described in Equation 34.

$$_tP_{t+n} = P_{t+n} \tag{34}$$

This form of expectations is difficult to examine in the way employed above. Imagine an event effects the market such that it is expected to increase the price of timber in the near but not the distant future. If the growing stock is very young the critical periods that are influencing the decisions of forest owners will be in the distant future and so $_tPM$ will not change. However, if the growing stock is very old it is the periods in the near future that are more likely to be important and so $_tPM$ will increase.

To examine this model of expectation formation a graphical approach will be employed. In the diagrams to be employed a supply curve S will be drawn which shows the supply in an equilibrium market in the sense that the actual price is evolving as expected (Nerlove, 1958). In the context of the simplifying assumptions here this implies that the current price and the expected price $_tPM$ are equal.

Independent, Transient Errors

In Figure 1 a transient shock shifts the demand curve from D to D_t. As the demand curve is expected to fall back to D in the subsequent period the supply will be given, not by S, but by S_t which shows the supply if the next period's price expectation is

P. As curve S is drawn on the assumption that price expectations equal current price, S_t will lie to the right of S at prices above P and to the left of it at prices below. Price instantaneously rises to P_t but is then expected to fall back to P in the next periods. Thus, PD_t will be negative and PD_{t+1} zero and there will be no relationship between price differences.

Price does not rise as much as it would with the simple naive expectations model. Forest owners realise that the present demand situation is favourable but temporary. Therefore, supply increases beyond the level if forest owners wrongly believe that the increase in price will persist into the future.

Serially Correlated, Transient Errors

This case is shown by Figure 2. The demand curve moves from D to D_t in period t and then is expected to fall to D_{t+1} in period t+1 and finally revert to D. In period t supply will be given by curve S_t drawn in the expectation of falling prices and the price will rise to P_t. In the next period the supply curve will fall to S_{t+1}, again partly to the right of S and finally it will move back to S as the market regains equilibrium. Unless the supply functions S_t and S_{t+1} are horizontal and pass through P, both PD_t and PD_{t+1} will be negative.

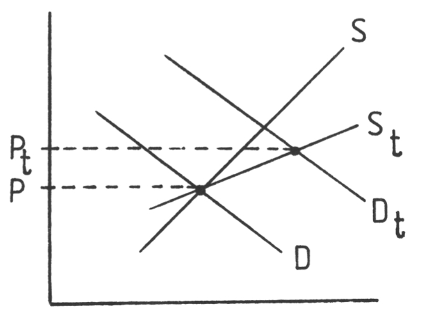

Fig 1. Random transient errors

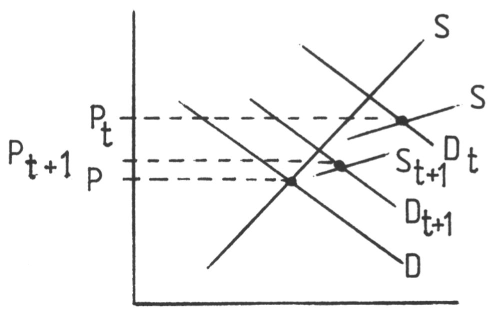

Fig 2. Serially transient errors

Independent, Persistent Errors

In this case the demand curve will shift permanently and forest owners will realise this. Thus, P_t will instantly rise and will be expected to remain at the new level. This case is indistinguishable from the naive expectations model.

Serially Correlated Persistent Errors

In a similar way it can be shown that rapidly incorporated errors leave no serial correlation in price time series whereas slowly incorporated ones do. In a similar way to the earlier argument, a "positive" error in demand will lead to a greater instantaneous jump in

P_t than in other models because the anticipation of future price rises reduces supply.

Distributed Rational Expectations

It is difficult to justify the previous model in any way except by arguing that forest owners understand the true nature of the market. However, if we assume that an individuals expectations of future price contain a forecasting error which is unbiased other interpretations of "rationality" are open and the same results can be achieved. For example, by observing prices only it might be possible that forest owners evolve a method of forecasting price that is inexact but unbiased. Thus, they may arrive at this version of rationality in a reasonable way. This poses the question, not addressed here, of whether such a learning process is possible and profitable given the nature of the market (Decanio, 1979).

ON TESTING THE MODEL

The results above imply that testing price differences for serial correlation cannot discriminate between the different types of price expectation formation mechanisms suggested.

However, the results of such an analysis of the correlation structure are useful. Two of the expectation structures suggested, rational and distributed rational expectations, imply that that forest owners understand the nature of the market in some way. Unlike other expectation mechanisms, rational expectations imply that forest owners do not consistently make mistakes in the application of the felling rule in Equation 2. The only source of error in their decision is the unpredictable random error that is left in the system after they have predicted and incorporated the future effects of serially correlated errors.

For example, if there was a single, transient, independent error in demand - cf. Fig. 1 - some forest owners forming expectations according to the simple naive method would not fell only to be **predictably** disappointed by the subsequent drop in price. In this case it would be possible to improve profitability by improving the forecasting method. If expectations were rational those not felling in period **t** at the temporary high price will be those whose forests would be better felled at the future lower price.

If expectations are rational it is not be possible to improve profitability by the use of easily available information and if simple reasonable rules, derivable from a historical analysis of the market, would have improved profitability over a period the implication is that expectations were not rational over that period. Note that it might be found that simple rules cannot improve profitability but that expectations might still not rational. If simple naive expectations are used and all errors are independent and persistent market participants will be correct in their expectations but without knowing why.

To test this idea the following procedure was employed. A test for serial correlation in prices was performed and simple felling rules derived that might increase profitability formulated. These were tested against the strategy of felling regardless of the indications of the felling rule and the profitability of the strategies compared.

A Runs Test of Price Differences

Monthly price data for standard sized logs of sugi, (Cryptomeria japonica) and hinoki (Chamaecyparis obtusa) for the period April 1975 to December 1983 were collected. The prices were deflated using the Wholesale Price Index of the Bank of Japan and then price differences were formed. In this way the 105 prices for each species gave 104 differences.

If changes in price are independent the expected number of runs, m_r, and the standard error of the mean, s_r can be given by Equations 35 and 36. N refers to the total number of price changes, n_1 represents the number of price increases, n_2 the number of periods in which the price did not change and n_3 the number of falls in price (Fama, 1965).

$$m_r = \frac{N(N+1) - \sum_{i=1}^{i=3} n_i^2}{N} \qquad (35)$$

$$s_r = \left[\frac{\sum_{i=1}^{i=3} n_i^2\left[\sum_{i=1}^{i=3} n_i^2 + N(N+1)\right] - 2N\sum_{i=1}^{i=3} n_i^3 - N^3}{N^2(N-1)}\right]^{0.5} \qquad (36)$$

The expected number of runs and the standard error along with the actual numbers that were found in the data are given in Table 3. For large samples (over 20 runs) the distribution of the total number or runs is approximately normal with a mean of m_r and standard deviation of s_r. The difference between the actual number of runs, R, and the expected number can be expressed by means of the standardised variable K defined by Equation 37 and given in the table.

$$K = \frac{(R + 0.5) - m_r}{s_r} \qquad (37)$$

The probabilities that consecutive price changes independent are given in the table. The probability of observing the 40 runs in the sugi data would be 1.3% and the 43 runs in hinoki would be 1.5%. Further analysis of the runs shows that, apart from one or two long downward runs, the distribution of downward runs was the same as that implied by the assumption of randomness in timber prices but that the average length of the upward runs was longer.

TABLE THREE

RESULTS OF THE RUNS TEST

Species	m_r	s_r	Actual number of runs	K	probability
Sugi	50.6	4.56	40	-2.219	0.013
Hinoki	53.8	4.73	43	-2.167	0.015

Strategies for Timing Felling

Imagine that forest owners find the time or other resources to consider the possibility of felling their timber in period **t** and find that felling in period **t** appears to maximise net present value. If expectations are rational no better decision can be made given the information available at **t**. However, if expectations are not rational it might be possible to improve on this decision by a closer examination of the information available at **t**. Assume that the forest owner is aware of the prices of timber in the past and that upward trends, although rarer than downward ones tend to persist longer. We can identify the following strategies.

Strategy A Fell the stand of timber in period t regardless of the path of timber prices in the immediate past.

Strategy B If the price has risen between periods **t-1** and **t**, defer felling until period **t+1** otherwise fell in period **t**.

Strategy C Follow strategy B unless the two previous two periods have seen price rises. If this is the case forest owners feel the price rise has finished and decide to fell immediately.

Strategy D If the price has just risen wait until the period **t+1**. If it rises again fell in period **t+2**. If it does not rise fell in period **t+1**.

The profits from the strategy A can be defined by Equation 38.

$$NPV_a = P_t V(T) + F \qquad (38)$$

The net present value for strategy B will either be given by Equation 38 or 39 depending on whether the forest owner decides to wait.

$$NPV_b = \frac{P_{t+1}V(T+1) + F}{(1+r)} - \frac{(P_t V(T) + F)r}{(1+r)} \qquad (39)$$

The first term shows the present value of felling the forest in period **t+1** and the second term shows the loss from not felling the forest in period **t**. The net present values from other strategies can be defined in similar ways. Using monthly data it is reasonable to ignore increases in volume that accrue from waiting. Assume further that the interest rate is zero and that the effect of deferring F for one period is negligable. This will tend to lead to the overestimation of the benefits of waiting. Defining volume as one unit and simulating the strategies over the periods in the data above Table 4 results.

The t-statistics relate to the means of the benefits from waiting and show the significance of the mean benefit defined as the average profit (or loss) from waiting calculated for those periods when waiting was indicated by the strategy.

TABLE FOUR

RESULTS OF ATTEMPTING TO "FINE TUNE" THE FELLING AGE

	Hinoki				Sugi			
	A	B	C	D	A	B	C	D
Average NPV	56670	56034	56569	56601	29424	29505	29694	29817
Standard deviation	11634	11653	11723	11206	6953	6968	6205	6408
Number of waits	0	40	18	40	0	36	18	36
Mean benefit of waiting	-	-221	449	-794	-	231	743	68
Standard devn of waiting	-	4806	4921	4271	-	1600	1718	1703
t value	-	0.05	0.09	0.19	-	0.14	0.43	0.04

CONCLUSIONS

The tests undertaken support, if only weakly, the idea that the market for timber in Japan is characterised by rational expectations. None of the simple strategies put forward gave significant benefit. The inference is that any expected future price change is not large enough to make it profitable for forest owners to wait. If expectations are indeed rational it follows that forecasting the output of NIPF is Japan or modeling the market in any way must produce results that are compatible with the assumption of rationality.

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SOME DEVELOPMENTS IN MODELING OF INTERNATIONAL TRADE IN FOREST PRODUCTS*

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ABSTRACT

The article discusses experience with modeling of long-term development of production, consumption and international trade in forest products. The basis is on research carried out in the Forest Sector Project at IIASA in 1981-85. However, we shall concentrate on some developments since the IIASA project was completed. This includes a study of possible consequences of air pollution in central Europe, a case in Finland for demonstrating how the IIASA model may be adapted to analyze alternatives for national or regional forest sector policies, and a review of some recent developments in modeling methodology including a PC software for GTM.

INTRODUCTION

The purpose of this article is to discuss some recent work related to the Global Trade Model (GTM), which was developed at IIASA (International Institute for Applied Systems Analysis, Laxenburg, Austria) for studying long-term development of production consumption and international trade in forest products (Kallio et al., 1987). First, we shall review a study on economic impacts of possible forest damage due to air pollution in central Europe. Key assumptions concerning forest mortality and growth impacts shall be made, and their consequences in timber and forest products markets shall be discussed based on GTM-simulations. Second, a simplified version of GTM is discussed and its use in forest policy analysis will be demonstrated. A

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single region model with export demand and import supply functions for forest products is employed to study consequences of a proposed long-term plan for timber production in Finland (The Forest 2000 Programme, 1986). Third, a review of methodological developments of GTM covers a new solution algorithm for the model as well as an entirely revised software of GTM. The new algorithm replaces the MINOS optimization package currently in use. It is efficient and easily implementable in a micro computer. The revised GTM software employs this algorithm. Furthermore, the data base has been reorganized with the aim of having the model as transparent as possible.

ECONOMIC IMPACTS OF ATMOSPHERIC POLLUTION IN EUROPE

This section is based on nine scenarios developed to study impacts of acid rain in Western Europe. We shall discuss the report by Dykstra and Kallio (1986) who study the forest economic consequenses within Western Europe. We shall point out some trade impacts in Northern Europe and North America based on these scenarios.

The analysis is based on the IIASA base scenario (Kallio et al., 1987) and the acid rain impacts are reported as changes relative to the base scenario.

Two kinds of pollution impacts on forests are considered. First, in shorter term a forest dieback occurs over a period of ten years starting in 1985. The resulting sanitary harvests yield an extra timber supply in Western Europe, which is given as a percentage relative to total removals in Western Europe in the base scenario. Four values for this percentage were tried: 10 %, 20 %, 33 % and 100 %, in scenarios six to nine, respectively. Due to adjustments in the timber stock, no pollution impact was assumed after 1995 in these scenarios. The second effect of pollution is a change in the timber stand growth rate. In scenarios three to five, a decrease of 50 %, 33 % and 10 %, respectively, was assumed in the annual growth rate. This change takes place indefinitely starting in 1985. Scenario two is a combination of scenarios four and seven; ie. it assumes a salvage harvest of 20 % relative to the base scenario and a growth decrease of 33 %.

Figure 1 shows qualitatively the mortality effect in timber harvests, sawnwood production and sawnwood consumption in Western Europe relative to the base scenario. In the timber harvests, three phenomena seem important. First, due to inertia in the timber markets, harvests increase gradually over the ten years even though the extra supply is constant. This can be explained by the fact that it takes time for the forest industry and international trade in forest products to adjust to the changing timber supply in Western Europe. Second, the peak in harvests at the end of the ten year period is much smaller than one would obtain by adding the salvage on the top of the harvests in the base scenario. The reason: approximately one half of the salvage harvests substitute normal harvests; ie. increased supply decreases timber prices and thereby normal harvests decrease. Third, after the ten year period the impact in harvests is small. This is due to the fact that the impact of slightly increased harvests over the ten years has a relatively small impact in the growing stock.

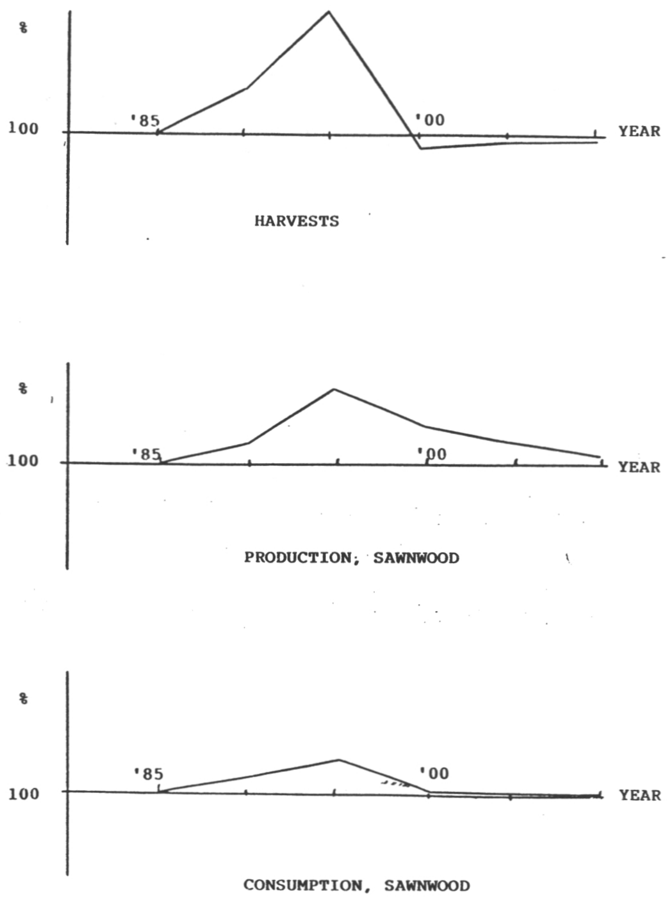

Figure 1. Timber harvests, and production and consumption of sawnwood in a forest mortality scenario relative to the base scenario in Western Europe.

According to Figure 1, sawnwood production in Western Europe follows a somewhat similar pattern as the harvests. However, there are two qualitative differences. First, the relative peak in 1995 is smaller than in the case of timber harvests. In general, it was observed that the smaller is the share of wood in production costs, the lower is the peak. Therefore, the impact on paper production was almost negligible. Second, the increased production in 1995 resulted in capacity, which remainded active also after the excess supply of timber was over. Thus production remains above the level of the base scenario also after the ten year period. Given simultaneous changes in timber harvests, this has obvious consequences in international trade of timber primarily affecting Northern and Eastern Europe.

Finally, Figure 1 illustrates relative changes in consumption of sawnwood, which clearly increases with increasing production. However, the peak in this case is even more weak than in the case of production; ie. consumption is relatively stable irrespective of the scenario assumptions. For these reasons, a decrease in sawnwood imports, primarily from Northern Europe and North America, is observed.

Figure 2 illustrates the growth effect in timber harvests, sawnwood production, and sawnwood consumption in Western Europe qualitatively relative to the base scenario values. A general observation is that the effect grows stronger along the time. The reason is that, due to long rotation time the impact of decreased growth rate in the growing stock takes place very slowly. In a long term, one would expect the sustainable harvests to drop approximately by the same percentage as does the growth rate of the timber stock. However, by the end of the fifty year horizon of our simulation, only about two thirds of this decrease has taken place.

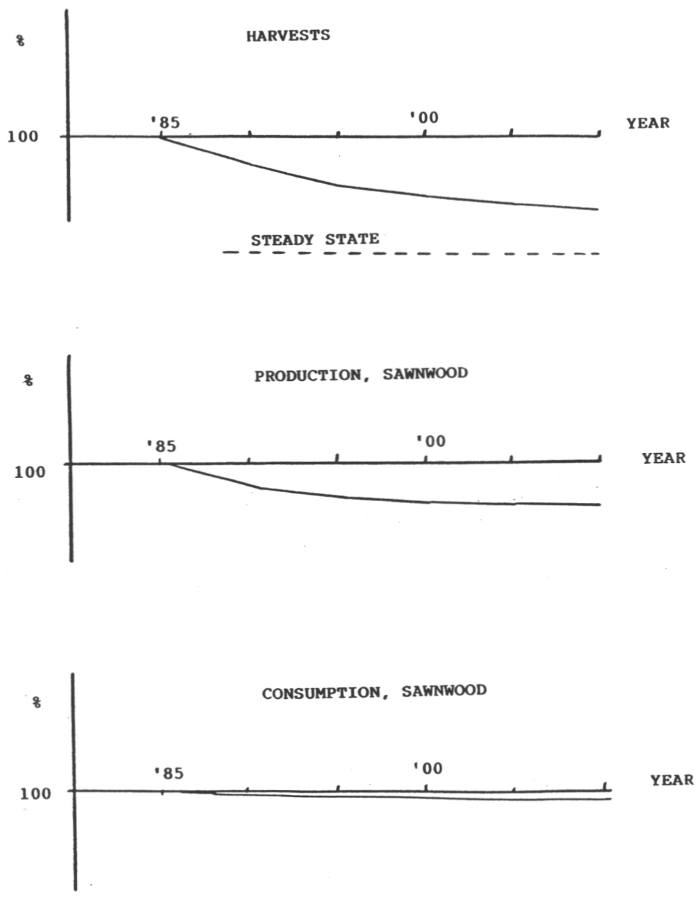

Figure 2. Timber harvests, and production and consumption of sawnwood in a decreased forest growth scenario relative to the base scenario in Western Europe.

The growth impact on production follows the phenomenon of the harvests, except that the impact is weaker, and again, the more so the lower is the share of timber costs in total production costs. Also in these scenarios, the consumption effect is close to negligible thereby increasing import demand.

From the discussion above it may be observed, that mortality has mainly short term consequences whereas decreased growth has its most significant impact in longer term. Therefore, the combined impact is approximately separable in time. Consequently, phenomena in scenario two are approximately obtained by summing up the effects from scenarios four and seven.

A POLICY ANALYSIS APPLICATION IN FINLAND

In this section we shall briefly illustrate the use of a modification of GTM in analyzing long term structural changes of forest industries in Finland. The starting point is The Forest 2000 Programme prepared by a committee of the Economic Council of Finland. The report proposes the annual cut to be increased by 15 mill. m^3 by the year 2010. The purpose of our exercise was to integrate this plan to the forest industrial processing. Because most of the production is exported, such integration shall include international trade of forest products as well.

Obviously a number of policy issues are of main relevance in such an analysis. They include exchange rate policies, labor markets, energy policy, and other factors determining the cost structure. In the following we shall discuss only two scenarios. They aim to shed light on the question of wood raw material costs (see also Kallio, 1987).

The model being used in the analysis is a productwise disaggregated and regionwise aggregated version of GTM. More precisely, 25 product categories were employed to reflect the product groups of main interest to the country. Only Finland is considered explicitly and the interaction with other regions is represented by export demand functions for final products and import supply functions for intermediate forest products.

An interpretation of the resulting model is an objective to maximize the total profit on timber resources; ie. the profit before the stumpage costs for the entire country. From the macro economic point of view this is roughly the same as maximizing the forest based increment of GNP while taking into account alternative uses of national resources such as labor, capital and energy. From the point of view of forest industrial companies, under perfect competition this corresponds to directing investments for maximizing profits. The model does not deal with the problem of income distribution, for example, between the industry and the forest owners. It only tends to maximize "the pie " to be shared.

Key assumptions concerning the base scenario A in Figure 3 are as follows. As a starting point we have the forest industrial production structure in 1985. We assume timber availability as given by the Forest 2000 Programme. However, all this wood may not be used, if it is not economically feasible for the industry. We assume a conservative zero growth for the export demand of mechanical forest products and pulp reflecting recent reports by FAO (1986) and The Timber Committee of ECE (1986). Similarly we assume a four percent annual increase for the export demand of paper. Exports are price elastic so that trade resulting from the model are endogenous. We assume a price elasticity of 2 for mechanical and 10 for chemical forest products. At the beginning the prevailing price and cost structure is used. The future cost structures depend on investments in various product lines. Stumpage costs are endogenous. They result from the difference between the timber price and the marginal cost of timber.

The market equilibrium implies that timber resources end up to product lines as an outcome of price competition; ie. the product line which can offer the highest price receives the wood. Scenario A of Figure 3 illustrates the resulting total timber consumption over the period 1985 - 2010. Total cuts grow from the annual level of 46 mill. m^3 in 1985 to 54 mill. m^3 in year 2000 and to over 60 mill m^3 by 2010. The graph is cumulative over timber assortments (birch logs, spruce logs, pine logs, birch pulpwood, etc.) used in various industrial processes. The lowest solid line yields the total use of logs in mechanical forest industries. As one might expect, because of the zero growth assumption of export demand, this quantity remains stable around 20 mill. m^3 per annum.

However, it is worth noting that despite the high growth assumption in the paper sector, mechanical industries remain competitive over wood raw material; ie. logs are not used for pulping to any larger extent. The growth in timber consumption is due to growth of the paper sector, particularly the printing paper production. Finally we may observe that some of the timber resources of the Forest 2000 Programme (the top line in the figure) remain unemployed under assumptions of this scenario.

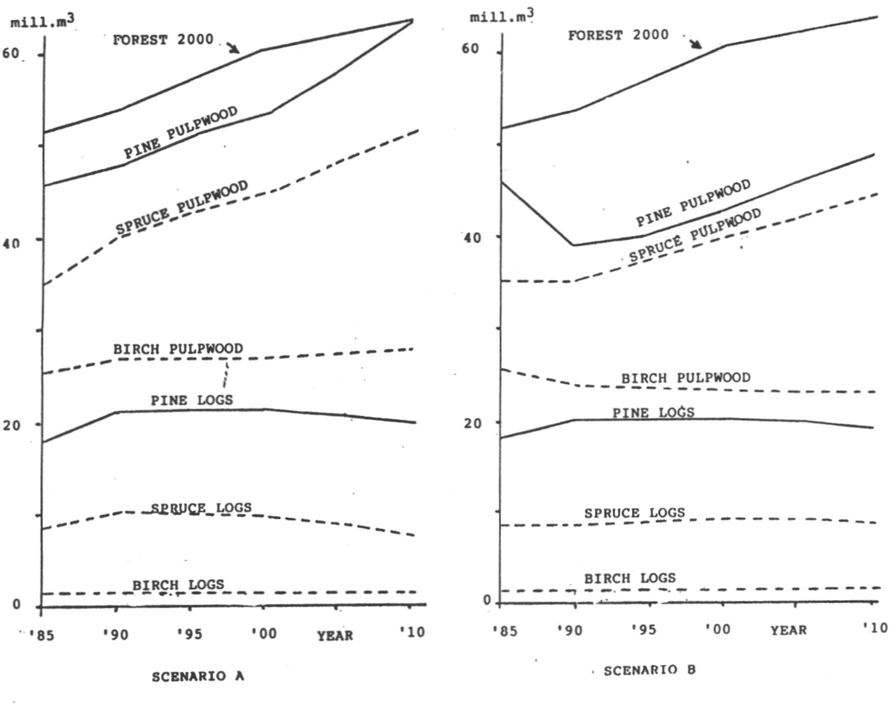

Figure 3. Distribution of timber use by timber assortment in scenarios A and B in Finland.

A specific question, which has received large attention in discussions about the future of the Finnish forest sector is the domestic price of timber. Relative to some major forest industry regions such as North America, timber price in Finland has remained high. Whether this fact endangers long term competitiveness of the Finnish products in the world markets has been subject to arguments. In the following we shall address this problem by changing the assumptions of scenario A. Instead of perfectly competitive timber markets, we shall assume that timber enters the market only if a given minimum stumpage price is offered. More precisely we shall require that at least the 1985 level of stumpage prices for the various timber assortments are met.

The resulting scenario B is illustrated in Figure 3 in terms of industrial use of timber. Some phenomena seem clear. First, forest utilization decreases drastically as compared with the base scenario A. In year 2000, 18 mill. m^3 of available timber according to the Forest 2000 Programme remains idle. The total cut decreases in short term and recovers only after the paper demand grows strong enough. Consumption of logs by mechanical forest industries remains approximately at the level of the base scenario A; ie. mechanical industries are relatively unaffected by the stumpage price requirement. The pulp and paper sector on the other hand reacts very strongly. It does not seem to afford the pulpwood price requirement.

SOME METHODOLOGICAL DEVELOPMENTS RELATED TO GTM

In this final section we shall discuss some advances related to the modeling software of GTM. A practical handicap of the software developed at IIASA is that it takes hours of CPU time even in a powerful computer to run a single scenario. From real policy analysis point of view it is desirable that impact of changes in scenario assumptions can be evaluated quickly. This goal was met by developing a new solution algorithm to substitute the MINOS optimization code, which originally was employed by GTM. Another major change was to reorganize the GTM database in such a way that it is easier for the model user to digest important aspects of the data. Finally some minor changes in the model formulation have been introduced.

The new algorithm to solve a partial equilibrium model, such as the model in each time step of GTM, is based on Gauss Seidel type of iterations to solve for the equilibrium conditions. From the optimization point of view, this may be interpreted as a modification of the Simplex Method adapted for nonlinear objective functions. From the point of view of economics, it can be interpreted as an imitation of the market process in a competitive environment where each agent in the economy, such as forest owners, forest industrial companies and the agents handling international trade, is a profit maximizer.

Compared with the MINOS code the resulting algorithm appears tens of times faster for GTM. Furthermore, the code is simple, in fact about fifty Fortran statements, it is robust with respect to numerical instabilities, and it is economic from the point of view of core requirements. Therefore, it allows GTM to be solved even in a micro computer environment. Details of the algorithm as well as a Fortran code are given in Kallio and Salo (1987).

A revised version of the GTM software is expected to be completed in the near future. It is based on the algorithm described above. The same flexibility to allow changes in regional aggregation, product aggregation, etc. shall be implemented as was the case in the software developed at IIASA. As an example, the 18 region and 16 product model with the base year 1980 which was developed at IIASA is included in the software. The data base, however, has been reorganized. The technological conversion coefficients, marginal production costs and capacity utilization limits have been organized productwise in order to make inter-regional comparisons easier. The same applies to harvest yield coefficients. In order to gain a better understanding on what is assumed about trade flows, the activities to be included in the model are indicated productwise by export-import matrices. The same matrices indicate the base year trade or, in the case of fixed flow, the level of trade in the model. These changes in the trade data are important because only a selected fraction of all possible flow combinations are incorporated in the model.

Again, for the sake of interregional comparisons much of the remaining data has been put into smaller tableaus of parameters by region. They include the base year data for production, consumption, prices and investment costs by product as well as the timber supply data and a number of regional parameters, such as capital supply parameters, trade inertia coefficients, and GNP and population data.

The main changes in the GTM formulation relate to the capital. First, capital supply for market economy regions is now handled with nonlinear supply functions which shift over time along with the business volume. For planned economies, export revenue and import budget constraints in the original GTM are replaced by capital demand functions for net export revenue. Finally, bilateral capital trade is formally included in the model. This allows lending, borrowing and foreign investments to be considered. Furthermore, joint capital supply for countries which are split into several regions can be handled in a natural way. In the original GTM the latter applies to USA and Canada.

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METHODS FOR IMPROVING THE REPRESENTATION OF BILATERAL TRADE FLOWS IN SPATIAL EQUILIBRIUM MODELS

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ABSTRACT

Accurate prediction of bilateral trade flows remains a persistent problem in spatial equilibrium modeling. The fundamental difficulties in trade flow modeling are reviewed. The two basic methodologies for handling this problem -- quantity constraints imposed through trade inertia bounds and trade bans, and value constraints imposed through quality penalties and premiums -- are presented and the merits and drawbacks of each are discussed. Simulations with the IIASA GTM are used to demonstrate the effects of these alternative methodologies on model performance. The analysis suggests that on both theoretical and empirical grounds, the prospects for using spatial equilibrium models to develop useful predictions of bilateral trade are poor. For predictions of more aggregate concepts such as production, consumption, and prices, spatial equilibrium models using value constraints hold the most promise.

INTRODUCTION

The identification and prediction of bilateral forest products trade has received a fair amount of attention among forest products analysts. This paper provides an assessment of current practices used to model bilateral flows in spatial equilibrium models.

Spatial equilibrium modeling has recently gained popularity due to the success of the IIASA Forest Sector Project. In a spatial equilibrium model, bilateral flows are determined such that all producing regions in the model maximize profits and all consuming regions in the model minimize expenditures subject to transfer costs (including both direct transportation costs and tariff charges) and constraints on each trading arc. The paper begins by reviewing problems with trade flow prediction in spatial equilibrium models, and considers alternatives for improving predictions in such models. These alternatives are then compared using three simulations of the IIASA Global Trade Model (GTM). (See Kallio, Dykstra, and Binkley (1987) for a description of the GTM.) Results are summarized in the final section.

CAUSES OF POOR BILATERAL TRADE FLOW PREDICTION IN SPATIAL MODELS

It is well known that spatial equilibrium models are poor predictors of bilateral trade flows. The reasons these models fail to predict bilateral trade flows accurately have been described by Brooks (1987), Adams and Haynes (1987), and Thompson (1981), among others. The primary difficulty is generally thought to be the violation of homogeneity assumptions at both the product and regional level.

Product definitions used in empirical analysis represent aggregations of more distinct items that are too broad from a theoretical standpoint. For example, coniferous sawnwood may include both high-grade specialty items and low-grade utility items. As a result of this aggregation, export prices may differ significantly from prices for the average product produced in a region, and import prices may differ from the average price of goods consumed. This aggregation also helps explain why cross-hauls are commonly observed in trade data: although regions are reported to be importing and exporting the "same" product, the imported and exported products may actually be quite different.

Recent data for the U.S. Pacific Northwest provides evidence of some of these problems. Data for Douglas-fir lumber produced in Western Washington and Oregon show 1987 prices ranging from USD 66 per 1000 board feet (MBF) for economy grades to USD 837/MBF for select grades (Warren, 1988). In 1987, the Pacific Northwest exported 1.6 billion board feet (BBF) of softwood lumber and imported 1.9 BBF. The average F.O.B. export price was USD 369 per thousand board feet (MBF), whereas the average price of imported softwood lumber was USD 229/MBF. The differences in export prices also was substantial: the export price for softwood lumber destined to the European Economic Community was USD 688/MBF, compared to USD 333/MBF for softwood lumber exported to Japan. (Trade data are from Chmelik, Brooks, and Haynes (1988).)

Similar aggregation problems arise with regional definitions. For a region to be homogeneous, it must have the same production costs throughout the region as well as identical transportation costs from all points within the region to the demand region. If supply and/or demand regions are large, the average transportation cost will poorly reflect the cost of shipping between regions. There is also a high likelihood that there will be significant variation in other production costs. Hence, large regional sizes increase the probability that one area of a region will actually import a commodity, while another part of the region exports the identical item.

While homogeneity violations are perhaps the most critical problem in determining trade flows, problems are also caused by the simplistic representation of economic behavior. Lack of realism in modeling economic behavior may make it difficult to model trade flows, even in the absence of product/region aggregation problems. "Pure" spatial equilibrium models assume that producers maximize profits and consumers minimize costs within a single solution period. But many other factors are likely to influence trading patterns. These include political factors, traditional marketing arrangements, long-term trading agreements, perceived differences among buyers, delivery performance, market uncertainty, expectations with regard to future markets, etc. (see Kornai, 1987).

METHODOLOGY FOR IMPROVING TRADE FLOW PREDICTION IN SPATIAL EQUILIBRIUM MODELS

Quantity Constraints

Because of the structure of spatial equilibrium models, it is easy to incorporate quantity constraints. Quantity constraints take two forms: fixed flows that exogenously specify the trade between two regions (trade bans are included in this category: trade flows are set to zero); and, inertia constraints that directly control the change in trade flows between the current period and next period. The GTM provides an example of a model that makes extensive use of both types of constraints. Another example of the use of inertia constraints can be found in Buongiorno and Gilless' (1984) spatial equilibrium model of the newsprint market.

Trade bans are clearly justified in a model when trade between any pair of countries is prohibited. For example, log exports are banned from Indonesia so trade bans should be implemented between Indonesia (the exporter) and all potential importing regions. Trade bans may also be used in a model to control trade flows that are not likely to occur.[1] In such a case, the analyst exercises direct control over the model solution. Trade bans were also used in the Forest Sector Project to eliminate trade flows and thereby reduce computational time and expense. Trade flows were excluded from the model either because they were small or nonexistent in the base year, or because they were not sufficiently profitable at base year prices and costs. Since

1. There are alternative methods of controlling such behavior. A common approach is to set transportation costs on an arc to some prohibitively large number.

alternative forest sector policies can have diverse impacts on potential trading partners and significantly alter trading patterns in the long run, this approach may lead to the loss of valuable information and bias simulation results.

Whereas the use and need for trade bans is clear, the use of inertia constraints needs more careful analysis. Trade inertia constraints take the general form:

$$L_{ijkt}\, Q_{ijk(t-1)} \leq Q_{ijkt} \leq U_{ijkt}\, Q_{ijk(t-1)}$$

where:

L represents the lower limit on the proportional change in Q_{ijk} from (t-1) to t (L is generally greater than zero and less than one)
U represents the upper limit on the proportional change in Q_{ijk} from (t-1) to t (U is generally greater than one)
i is the exporting region
j is the importing region
k is the product
t is the time period
Q is the shipment volume

There are numerous ways to implement inertia constraints in a spatial equilibrium model. The limits (or multipliers) may vary over time or between regions. They may also vary across products. In the Forest Sector Project, these limits were fixed for all regions, products, and time periods: L was set to 0.50 and U was set to 2.00.

There are major problems associated with inertia constraints. First, it is not possible to estimate the level and rates of change of the inertia limits (L and U) statistically and so they must be set arbitrarily. Statistical estimation requires that one isolate the true effect of inertia from the myriad of other factors that affect trade flows. Most importantly, trade flows adjust slowly because the relative cost structure among producing/exporting regions also adjusts slowly.

Second, when trade inertia constraints are binding in a solution, they cause delivered prices from exporting regions to deviate from the equilibrium price level in the importing region. As a result, imported products which are binding at the minimum flow will be delivered at a premium over the average good consumed, and imported products at the maximum bound will be delivered at a discount. While it is true that price differences are observed historically, two problems should be recognized. First, prices of various import flows do not differ randomly, but tend to show some systematic pattern of variation. One example is provided by the real prices of U.S., Canadian, U.S.S.R., and New Zealand softwood sawlogs delivered to Japan (Figure 1). It is clear that the relationship among these prices is quite stable over time. The ratio of U.S. and U.S.S.R. prices is plotted in Figure 2 to further highlight this long-run stability (this figure also demonstrates that relative prices may be erratic in the short-run). Stable price relationships cannot be replicated when trade inertia constraints are binding. Second, average historical prices for a

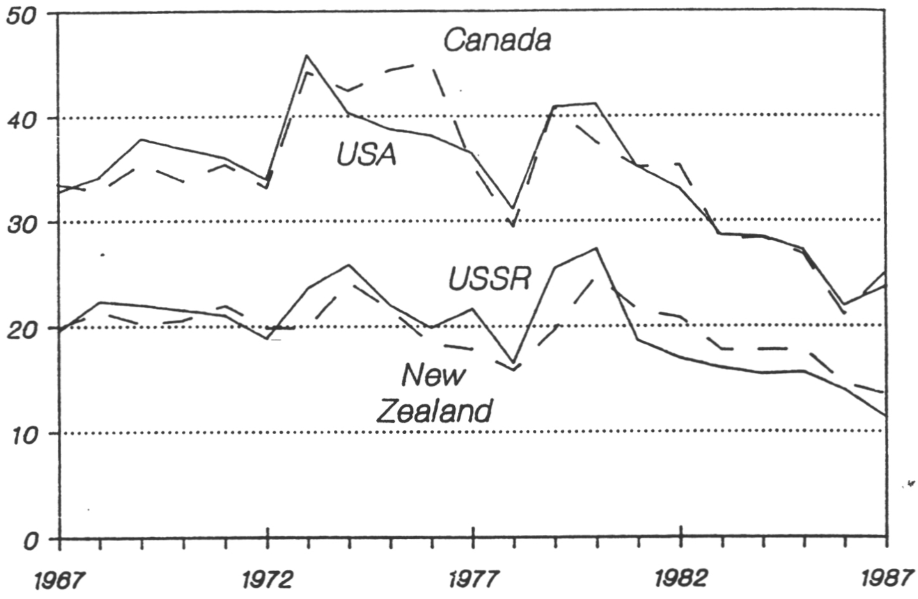

Figure 1. Delivered Price of Sofwood Sawlogs in Japan 000's of 1980 yen / cum

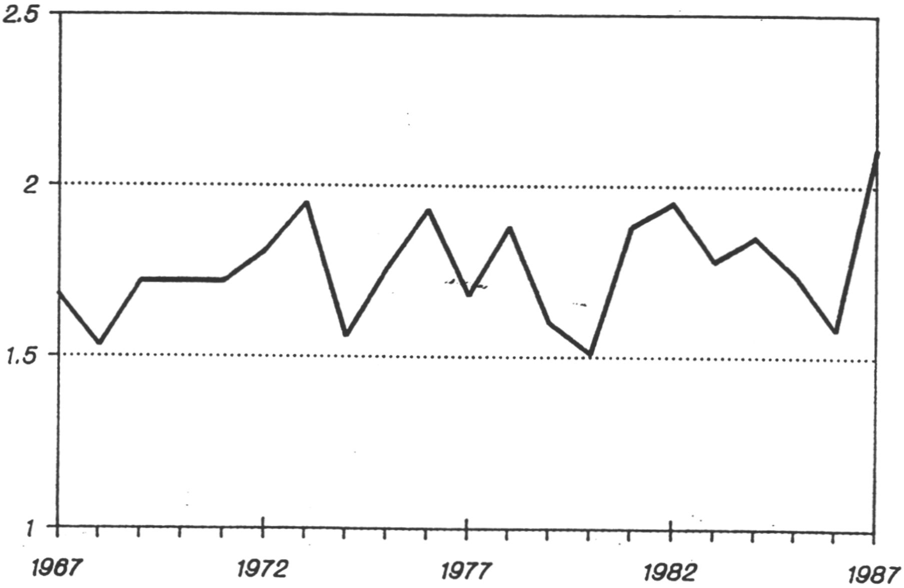

Figure 2. Ratio of US to USSR Price of Softwood Sawlogs Delivered to Japan

product consumed in a region are computed as a volume-weighted average of the prices of products consumed from different sources; thus, the prices of different imported goods and domestic goods affect the level of product demand. However, in spatial equilibrium models, a single price is determined at the margin in each consuming region so that markets clear. Import prices for products whose flows are determined on trade constraints have no bearing on the model solution, and the consumption price will not properly reflect the mix of imported products. Thus, although adjustments in quantities traded are slowed by the inertia constraints, price effects are not properly accounted for which results in noneconomic behavior.

Value Constraints

Value constraints provide another opportunity for altering the solution obtained from a pure spatial equilibrium modeling approach. Value constraints may be defined as:

$$P_{jkt} = P_{ikt} + T_{ijkt} + C_{ijkt}$$

where:

P represents the average product price
T represents the transfer cost
C represents the value constraint or adjustment (premium or discount)
i is the exporting region
j is the importing region
k is the product
t is the time period

Value constraints provide a means of altering the trading costs associated with an arc so that they reflect the different grades or species of a product, thus incorporating quality premiums or penalties. These may be incorporated by including a matrix of premiums or penalty costs or by directly altering the transfer cost (T) on an arc.

Value constraints are currently used in the Timber Assessment Market Model (see Adams and Haynes, 1980, for a description of the original model). The FORSIM Model, a spatial model of the North American softwood solid wood sector, uses a procedure which bears close resemblance to value constraints: market shares depend on the maintenance of price ratios that are consistent with historical patterns (see Cardellichio and Veltkamp, 1981). Apparently, value constraints were under consideration at IIASA.[2]

2. Personal communication with Markku Kallio, Helsinki School of Economics and Dale Kalbfleisch, Weyerhaeuser Company.

A COMPARISON OF PROJECTIONS USING ALTERNATIVE METHODOLOGIES IN THE IIASA GTM[3]

To analyze the effects of alternative methodologies in determining bilateral trade flows in spatial equilibrium models, we compare the results of three simulations in this section. The BASE is our point of reference and it incorporates the methodology used in the IIASA Forest Sector Project, that is, inertia constraints are implemented on trading arcs.[4] The inertia constraints are removed in a second simulation -- NO INERTIA, or NOI -- so that trade occurs freely. In the third case, we utilize value constraints instead of quantity constraints, and refer to this simulation as VALUE, or VAL. We implement value constraints, or quality differentials, simply by calculating the difference between prices for regions that trade in the base year.[5] The performance of the model under the three cases is judged using criteria described below.

Bilateral Trade Predictions

First, and most simply, we consider the diversity and concentration of trade flows in the three simulations. Table 1 presents the relevant data. The potential number of trade flows for each commodity is shown, along with the total number of positive trade flows occurring in 2000 (the fourth solution period). As we would expect, the pattern of trade is much more diverse in the BASE, closely corresponding to the diversity of trade that we have observed historically. The diversity of flows is similar in NO INERTIA and VALUE, but both simulations show dramatically fewer flows than the BASE.

Table 1 also presents five-flow concentration ratios, which indicate the percentage of trade accounted for by the five largest export flows. As we see from the 1980 data, historical trade is quite concentrated within each product group. Trade patterns are more concentrated in the BASE predictions for 2000; thus, in spite of the

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3. The authors thank Michael Pederson for his expert programming assistance in conducting the simulations in this section.

4. These constraints take two forms. One is the percentage change in the trade flow from the previous period. The second is the maximum growth in a region's trade for new or small flows. Trading constraints that fix flows between trading partners, for example, the USSR and Eastern Europe, are left intact.

5. The cost on any arc is computed as the maximum of the price difference between the trading regions in 1980. This cost is assumed to be relevant only when significant trade occurs in 1980. If trade is less than or equal to 0.5 million cubic meters or metric tons (admittedly, an arbitrary cutoff), the original transportation cost model used in the IIASA GTM applies.

diverse pattern of trade, many flows remain negligible in volume. The five-flow concentration ratios indicate that trade is even more concentrated in NO INERTIA and VALUE.

A second item of interest is the number of free (unbounded) trade flows in each simulation, since the theory concerning relative prices in spatial equilibrium models is valid only for unconstrained flows. For the year 2000, Table 2 shows the number of free flows, along with the number of bounded flows in the BASE and the corresponding percentage of traded volume that is bounded.[6] The number of free flows

Table 1
Number of Potential Flows, Number of Positive Flows, and Concentration Ratios for Three Alternative Simulations

	Number of Potential Flows in 2000	Number of Positive Flows in 2000			Concentration Ratios			
					History	2000		
		BASE	NOI	VAL	1980	BASE	NOI	VAL
Solid Wood Products:								
CSAW	72	61	11	13	67	67	83	71
NSAW	78	69	10	15	53	50	96	69
VEPY	89	71	9	6	68	96	99	99
BOAR	81	51	4	4	61	92	100	100
Paper and Paperboard:								
NEWS	92	63	12	13	77	89	92	90
PRNT	95	68	9	8	50	93	96	95
HHSP	83	42	4	4	49	95	100	100
PACK	107	83	12	14	51	63	84	75
Intermediate Products:								
RCYC	55	36	8	7	67	78	94	89
CWIP	99	67	18	14	54	69	74	85
NWIP	95	63	15	17	57	61	84	83
Raw Materials:								
CLOG	61	39	8	10	72	95	99	98
NLOG	68	48	5	9	92	97	100	96
CPWD	66	35	7	10	64	77	95	83
NPWD	60	8	6	6	100	97	100	99

Notes: 1) Products are defined as: CSAW, coniferous sawnwood; NSAW, nonconiferous sawnwood; VEPY, veneer and plywood; BOAR, reconstituted panel products; NEWS, newsprint; PRNT, printing and writing papers; HHSP, household and sanitary papers; PACK, packaging papers; RCYC, recycled papers; CWIP, coniferous "white" pulp; NWIP, nonconiferous "white" pulp; CLOG, coniferous sawlogs; NLOG, nonconiferous sawlogs; CPWD, coniferous pulpwood; NPWD, nonconiferous pulpwood.

2) BASE, NOI, and VAL are defined in text.

3) Concentration ratios are defined as the percentage (by volume) of world trade accounted for by the five largest export flows.

6. A very small percentage (by volume) of trade in NO INERTIA and VALUE is subject to bounds due to fixed flows between regions.

is quite similar in all cases. In spite of the improved realism in trade diversity and concentration that we observe due to the inertia constraints, much of the trading activity is heavily constrained. For example, for nonconiferous sawnwood, 82 percent of the traded volume moves on constrained arcs. This constitutes a serious problem because the inertia constraints are largely arbitrary. If one accepts the premise that free flows are a desirable feature of the model solution, then NO INERTIA and VALUE perform as well or better than the BASE.

Table 2
Number of Free Flows in 2000 for Three Alternative Simulations and Number of Bounded Flows and Percent of Bounded Volume in BASE in 2000

	Number of Free Flows			BASE Constrained Flows	
	BASE	NOI	VAL	Number	Percent
Solid Wood Products:					
CSAW	9	9	11	52	25
NSAW	7	9	14	62	82
VEPY	3	8	5	68	33
BOAR	2	3	3	49	45
Paper and Paperboard:					
NEWS	10	11	12	53	4
PRNT	7	8	7	61	8
HHSP	3	3	3	39	24
PACK	11	10	12	72	35
Intermediate Products:					
RCYC	4	7	6	32	52
CWIP	14	17	13	53	19
NWIP	12	14	16	51	44
Raw Materials:					
CLOG	3	4	6	36	32
NLOG	5	5	9	43	9
CPWD	4	6	9	31	32
NPWD	2	6	6	6	89

Notes: 1) See Table 1 for product definitions.
2) Percent refers to the volume of trade that is constrained in the model solution.

A third concern is the accuracy of individual trade flow predictions using the three alternative methodologies. A weighted average of absolute percent errors for 1980 is shown in Table 3. For NO INERTIA and VALUE, the maximum decrease or increase is always 200% because the denominator is defined as the average of the actual and predicted values. In contrast, the maximum changes are less for the BASE due to the inertia constraints. For each product group, bilateral trade flow predictions using inertia constraints -- the BASE case -- are almost always superior to the alternative methodologies. The comparison between NO INERTIA and VALUE is mixed, since neither methodology yields a dominant solution in the sense that it uniformly predicts more accurately. The most important conclusion is that all three methodologies produce extremely large errors: errors of the magnitude shown in Table 3 are clearly unacceptable for useful predictions.

Table 3
Assessment of Individual Trade Flow Predictions Using Three Alternative Methodologies

	1980 (Weighted Average of Absolute Percent Errors)			2000 (Weighted Average of Percent Changes)					
				Decreasing			Increasing		
	BASE	NOI	VAL	BASE	NOI	VAL	BASE	NOI	VAL
Solid Wood Products:									
CSAW	26	65	71	85	94	58	212	301	146
NSAW	54	118	76	83	96	100	1213	4172	822
VEPY	29	60	60	89	99	98	315	234	235
BOAR	27	57	45	87	94	100	1355	1502	830
Paper and Paperboard:									
NEWS	15	33	37	65	79	76	129	158	159
PRNT	38	82	78	85	100	100	774	713	418
HHSP	52	119	121	91	100	100	200	296	314
PACK	32	75	103	75	86	87	911	1422	505
Intermediate Products:									
RCYC	53	118	72	92	92	94	167	269	294
CWIP	43	86	118	71	81	91	160	314	286
NWIP	41	84	82	69	96	92	485	626	501
Raw Materials:									
CLOG	28	52	26	66	100	69	544	622	2165
NLOG	21	43	16	44	100	99	212	88	84
CPWD	44	99	79	75	100	100	216	338	267
NPWD	47	120	66	94	100	100	***	***	***

Notes: 1) For each trade flow, the percent error is calculated as: (predicted 1980 volume - historical 1980 volume) / [(predicted 1980 volume + historical 1980 volume)/2]. The volume weights are equivalent to the denominator.

2) For each trade flow, the percent change is calculated as: (predicted 2000 volume - historical 1980 volume) / historical 1980 volume. Again, the weights are equivalent to the denominator.

3) See Table 1 for product definitions.

4) *** indicates percent change exceeds 999999.

To consider further the nature of bilateral trade flow predictions, we examine the trade flow predictions for 2000 and evaluate them on the basis of how "reasonable" they appear. Table 3 presents the weighted average percent change in trade on each arc between 1980 (historical values) and 2000 for these simulations. Negative and positive changes are presented separately to emphasize the magnitude of the increasing growth in trade flows.[7] The results show

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7. 1980 values are used as the denominator in the growth rate calculation to demonstrate the change from historical values. As a result, decreasing flows may fall only 100 percent, while the increase in flows is unlimited. For this reason, these changes are presented

that the percent changes in individual trade flows are extreme for all cases. Although the increases in the BASE are tempered by the inertia constraints, the potential growth rate for historical flows generally is 1500 percent (based on a doubling of flows each period). Such rates of change appear to be much more rapid than suggested by historical trends (see Kornai, 1987).

Based on the above analysis, we conclude that all three approaches to modeling bilateral trade flows yield very poor and unreliable results. One could impose tight inertia constraints -- such as 0.95 for the lower multiplier and 1.05 for the upper multiplier -- and greatly improve the ability of the model to predict 1980 bilateral trade patterns. There are at least two objections to such an approach: 1) because the trade solution is so heavily constrained, the reasonableness of the predictions for future periods declines rapidly because future changes in supply and demand conditions in different markets are not properly filtered into the model projections; and, 2) one could generate such results in a more cost-effective manner by simply using naive or trend projections.

Aggregate Market Predictions: Trade, Production, and Prices

In this section, we address the ability of the model to predict more aggregate behavior using the three different methodologies. Consider first the accuracy with which the alternative approaches predict overall trade levels. For each of the three simulations, Table 4 shows percent errors in predicting world trade (exports equal imports at the world level), along with the weighted average absolute percent errors in predicting regional export and import levels in 1980.[8] BASE and VALUE clearly predict world trade more accurately than NO INERTIA. At the regional level, BASE predicts better than NO INERTIA, and generally better than VALUE (VALUE is preferred to NO INERTIA). Most importantly, as we observed for the bilateral trade predictions, the prediction errors are intolerably large for all simulations.

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separately. Note that because these flows are weighted by historical volumes, flows that are small initially receive relatively little weight.

8. There are 18 regions represented in the IIASA GTM.

Table 4
Aggregate Trade: Accuracy of 1980 Predictions

	World Trade (Percent Error)			Regional Exports (Weighted Absolute			Regional Imports Percent Error)		
	BASE	NOI	VAL	BASE	NOI	VAL	BASE	NOI	VAL
Solid Wood Products:									
CSAW	-13	-21	-9	14	29	26	19	34	25
NSAW	-15	-22	-15	21	45	39	34	73	34
VEPY	-14	-28	-27	20	34	33	16	29	28
BOAR	-20	-34	-27	20	34	27	20	34	27
Paper and Paperboard:									
NEWS	-8	-12	-9	8	12	9	8	12	10
PRNT	-18	-31	-30	21	39	30	23	41	32
HHSP	-38	-66	-56	38	73	73	33	58	58
PACK	-15	-27	-11	17	32	35	16	29	33
Intermediate Products:									
RCYC	-32	-54	-37	40	75	39	34	59	43
CWIP	-2	-12	14	18	34	57	26	41	62
NWIP	-10	-22	-22	15	29	29	14	26	26
Raw Materials:									
CLOG	-13	-26	-12	21	35	17	15	29	14
NLOG	-19	-33	-7	19	34	9	19	33	7
CPWD	-27	-47	-24	28	48	28	27	49	42
NPWD	-36	-72	19	39	75	22	39	77	32

Notes: 1) World trade refers to the level of total world exports/imports.
2) Regional trade refers to the volume-weighted absolute percent error in regional exports or imports.
3) See Table 1 for product definitions.

In Table 5, we present the errors in predicting world production, regional production, and regional prices in 1980. Predictions of world production are fairly accurate. VALUE generally predicts as well or better than the BASE -- both cases are nearly always preferred to NO INERTIA. Predictions of regional production also are reasonably accurate, whereas large errors occur in the prediction of regional prices. The ranking of simulations with respect to regional production and prices is the same as for world production -- VALUE is preferred to BASE, which is preferred to NO INERTIA. One of the most salient features of Table 5 is the generally superior performance of the VALUE simulation in predicting production and prices at the resource level.

Finally, predictions in aggregate concepts for 2000 are examined by comparing the different trajectories of the three simulations. Table 6 shows pairwise comparisons between BASE and NO INERTIA and BASE and VALUE. In each comparison the percent difference and absolute

Table 5
Production and Prices: Accuracy of 1980 Predictions

	World Production (Percent Error)			Regional Production			Regional Prices		
				(Weighted Absolute Percent Error)					
	BASE	NOI	VAL	BASE	NOI	VAL	BASE	NOI	VAL
Solid Wood Products:									
CSAW	-0.6	-0.9	0.1	0.8	1.3	0.3	7.3	8.4	2.9
NSAW	-0.7	-2.2	-0.1	0.8	2.2	0.1	5.3	9.8	7.9
VEPY	0.9	0.4	0.6	1.4	2.0	1.8	8.8	8.8	8.5
BOAR	-0.1	-0.3	-0.1	0.2	0.3	0.1	6.1	7.8	5.7
Paper and Paperboard:									
NEWS	-1.9	-2.2	-1.1	1.9	2.3	1.1	4.4	5.5	4.9
PRNT	-0.5	-0.7	-0.7	0.5	0.7	0.7	6.4	8.2	7.4
HHSP	-1.1	-1.7	-1.8	1.1	1.9	1.9	8.0	10.7	10.9
PACK	-0.5	-0.8	-0.3	0.7	1.1	0.6	5.5	6.4	4.5
Intermediate Products:									
RCYC	-0.4	-0.6	-0.4	4.6	7.7	4.3	6.6	8.5	5.4
CWIP	-1.3	-1.7	-1.3	7.6	8.2	8.5	10.0	8.5	8.5
NWIP	-0.5	-0.6	-0.6	0.7	1.1	1.0	6.7	5.6	6.6
Raw Materials:									
CLOG	-0.7	-1.1	0.2	1.8	2.8	0.7	12.0	13.9	5.6
NLOG	-0.6	-1.6	-0.1	4.4	6.9	1.2	19.4	24.1	4.4
CPWD	-1.1	-1.4	-0.7	4.3	5.4	3.0	43.3	51.0	23.3
NPWD	-0.3	-0.5	-0.3	2.5	4.7	0.6	32.7	35.9	26.1

Notes: 1) Regional trade refers to the volume-weighted absolute percent error in regional exports or imports.
2) See Table 1 for product definitions.

percent difference in production and exports by product group are shown. At the world level, production is similar in all three cases; however, the three methodologies produce radically different results in overall export levels. The differences are accentuated for predictions of regional behavior, and are far larger for regional exports than regional production. Clearly, the choice of bilateral trade methodology affects the long-run predictions in a substantive way.

Table 6
A Comparison of Production (Q) and Export (X) Volumes in 2000

	NOI vs. BASE World		NOI vs. BASE Regional		VAL vs. BASE World		VAL vs. BASE Regional	
	Q	X	Q	X	Q	X	Q	X
Solid Wood Products:								
CSAW	2	7	5	20	2	88	26	104
NSAW	4	11	12	67	3	28	14	65
VEPY	0+	-18	15	21	2	-97	59	97
BOAR	0+	-12	1	12	1	-26	3	26
Paper and Paperboard:								
NEWS	0-	5	11	15	1	17	18	23
PRNT	0+	-1	7	17	1	-10	24	64
HHSP	0-	-10	2	120	0+	-5	2	125
PACK	0+	-5	5	42	1	56	12	75
Intermediate Products:								
RCYC	-1	29	1	75	-1	32	8	54
CWIP	-1	-13	11	36	-1	8	33	97
NWIP	-1	-2	16	29	2	-13	15	17
Raw Materials:								
CLOG	2	-9	3	9	2	16	8	68
NLOG	3	18	6	40	4	70	6	91
CPWD	0-	2	3	40	0-	99	8	130
NPWD	-1	60	7	62	1	7	8	32

Notes: 1) World production and export figures indicate percent differences from the BASE projections.
2) Regional production and export refers to volume-weighted absolute percent differences from the BASE projections.
3) See Table 1 for product definitions.
4) 0+ indicates that the difference is greater than 0 and less than 0.5%. 0- indicates that the difference is less than 0 and greater than -0.5%.

SUMMARY

Inertia constraints can improve the projection of bilateral trade flows considerably, particularly in the early periods of a projection when their influence is most significant. This improvement is due to the relatively slow adaptation of trade flows over time. However, naive projections or simple extrapolation would be a more cost-effective and perhaps reliable method of obtaining such projections. Furthermore, when the bounds are made particularly narrow, they can cause large problems with regional production, consumption, and price forecasts. When the bounds are wide, they are only effective early in the projection period.

The theoretical basis for imposing value constraints to improve the representation of bilateral trade flows is more sound than that for quantity constraints. Empirically, bilateral trade flows are predicted poorly with the GTM using all methodologies, but the evidence suggests that value constraints provide a more realistic assessment of production, consumption, and price behavior.

These results suggest two important conclusions concerning the modeling of bilateral trade flows. First, at the level of product and regional aggregation used in the GTM, it is not possible to model bilateral trade flows accurately with a spatial equilibrium model due to unrealistic assumptions. Furthermore, it may also be difficult to predict overall trade levels (regional exports and imports) because of the prevalence of cross-hauls in trading activity. The solution to a spatial equilibrium model will not generate cross-haul behavior unless trade flows are constrained. Second, if one is interested in predicting regional production, consumption, and prices, accurate bilateral trade flow prediction is not necessary. This latter point is an important one and it can be readily demonstrated by model simulations that yield major changes in trade flow patterns due to minor changes in relative production or transfer costs.[9]

Because the above results are conditional on the original GTM structure, they are merely suggestive of the pros and cons for trade modeling alternatives in spatial equilibrium models. It should be noted that there many other theoretical and empirical problems with the specification of the original IIASA GTM (Cardellichio and Adams, 1988). Changes in the model that improve the specification would result in a more realistic structure and hence a more conclusive test of the effects of alternative methodologies on model behavior.

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9. A corollary of this result is that bad predictions of the relative production levels of different products may still yield reasonable predictions of production and prices at the resource level.

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M O V I N G   T O W A R D   A   N E W   S Y S T E M S   P A R A D I G M   F O R   F O R E S T   S E C T O R   M O D E L I N G   A N D   A N A L Y S I S[1]

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ABSTRACT

This paper suggests some alterations in the conceptual framework for evaluation of the forest resource system using systems analysis techniques, and it emphasizes technology change as an endogenous component. The systems analysis concept presented departs from much of previous forest sector systems analysis literature in that a mathematical model with an equilibrium solution does not have to be the central component of the problem solution. Technological change is an important part of the system. Technological innovation induces an element of disequilibrium into the system that is neither entirely controllable nor chaotic, but it leaves the equilibrium solution indeterminate in a dynamic system. Furthermore, technological systems are closely related to and intertwined with social and political systems. An evolutionary approach is suggested for long-term analysis of economic growth and technological change.

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INTRODUCTION

Systems analysis provides a way to look at forest resource economics and development to broaden the perspective of management decision making by considering factors other than the resource base. The forest resource system, a set of interacting variables, is part of a larger system that is the sum of human experience and defines the value of forest resources, according to Duerr et al. (1979). Most systems analyses of forest resources concentrate on the timber-output system, which consists of timber inventory, timber growth, timber management, and timber removal. This is the major part of the timber resource system from a forester's viewpoint; however, from an overall systems analysis viewpoint, the other components, the forest product conversion subsystem and the market and consumption subsystem are also important. Nontimber values and outputs are also important, but these will not be considered in this paper. The forest resource system is dynamic. It changes continuously through time in many dimensions--biological, technological, economic, sociopolitical--that are changed through management activities.

The conversion process for forest resources is part of the overall forest resource system (Bethel and Schreuder 1976). The conversion process is a function of resource supply and marketing systems available to the resource. Thus, a forest-based conversion process will typically have a high efficiency for high-valued materials like black walnut, mahogany, or rosewood. However, the efficiency can be much lower for low market value raw material like aspen. Changes in the forest-based material supply system occur slowly over long periods and generally require considerable expense (Bethel 1980).

The forest-based materials supply is biologically renewable and changes through time. Manipulation of the forest and the manufacturing facilities permit progressive improvements in utilization efficiency. With the use of process conversion models and proper data, the forest materials supply system can be evaluated in terms of utilization efficiencies. In a similar way, the flow of capital, energy, and labor can be evaluated through the material production system. Environmental considerations can be considered as constraints on the system. This subsystem can then be integrated with other subsystems of the forest resource system. Technology changes occur over long periods of time. These technological changes influence wood utilization efficiencies. The rate of technological change in turn can be affected by forest products research efforts.

OVERVIEW OF SYSTEM ANALYSIS CONCEPTS

Any forest sector systems analysis involves the transformation of a certain combination of available inputs (resources and technology) into desirable outputs (products and/or services) within a given framework (technical, socioeconomic, political-legal). The systems approach involves the comprehensive analysis of this process from the point of view of the whole system. The systems approach is a conceptual framework for visualizing and comprehending a decision problem in a rational and objective way, beginning with basic premises and proceeding to conclusions. At the heart of the systems approach is a notion that problems must be seen in their entirety over time. The parts (subsystems) that constitute the whole (system) are dynamically interrelated in such a complex way that the whole is more than the sum of the parts. The whole determines the nature of the parts, and the parts cannot be properly understood if considered in isolation from the environment (Sharif 1978).

The systems analysis concept presented here departs from a good deal of previous system analysis literature in that a mathematical systems model does not have to be the central component of the problem solution. The central component of analysis may be quantitative, qualitative, or mixed. This may be an expert or computer information system. Methodological tools considered for systems analysis run the gamut from behavioral research into what exists, through values research into what is preferred, to normative research into what should be.

A major distinction between the method in systems analysis and that of the pure scientific method is the inclusion of the decision maker. At some point in real world systems a decision on policy or action must be made. It may be based on scientific considerations or upon other considerations. The task of the systems analyst is to bring together the best scientific information in a systematic fashion for evaluation by the decision makers.

QUANTITATIVE TOOLS IN SYSTEMS ANALYSIS

Systems analysis is impossible without some degree of quantification. Quantitative measurements allow us to organize knowledge, to compare results over time and space, to use mathematical methods to test hypothesis derived from scientific theory, to optimize system performance based upon alternative criteria, and to simulate present and future system output. It allows aggregation and manipulation of data in management information systems using more powerful and accessible computers. The ability to abstract the physical and social world into quantifiable models has been a major contributor to scientific, technological, and social progress.

An important aspect of the success of a modeling effort is the choice of the correct mathematical structure to represent the system under study. This surrogate system must represent the "real system" and the problems to be solved by decision makers or managers in a realistic manner. It is convenient to represent the set of mathematical paradigms into four principal components (Casti 1987). These categories are Operations Research (OR), Computer Science (CS), Control Theory (CT), and Systems Theory (ST). These specific techniques can be further classified as deterministic or stochastic.

Operations Research problems generally revolve around issues of planning, scheduling, and resource allocation. Methodologically, the techniques used are traditional OR tools: resource allocation, scheduling theory, inventory control, and decision analysis.

Computer Science has developed operating systems and new computer languages to manage information and is used in conjunction with Artifical Intelligence/Expert Systems techniques. These systems can also be used with OR or CT methods.

Control Theory, which arose out of aerospace and mechanical engineering problems in the 1960s, contains the concepts of systems feedback, adaptive change, uncertainty, and complex hierarchy.

Generally speaking, the models, tools, and techniques of OR, CS, and CT start with a particular formal structure and try to fit problems to them. The basic problem revolves around how various applications can be addressed within the selected paradigm or technique.

Systems Theory differs in an important way from conventional OR or CS methods. A Systems Theory view focuses more upon paradigm construction than upon techniques and algorithms associated with a given framework. One starts with the framework, or point of view, and explores how important concepts or issues might be addressed. The object of the ST is to develop a set of techniques or paradigms that meet the objects of the system based in a relational rather than structured way.

As important as quantification is to remove uncertainty and guide management decision making, the art of quantitative systems analysis still lies in the analysts' and decision makers' ability to judge which uncertainties are being removed advantageously and, conversely, which ones fit the Procrustean metaphor. Correct application of quantification will usually make the difference in whether the model or analysis fits its intended purpose.

Well defined and documented quantitative analysis is usually the preferred method of analysis and problem solution. There is a limit to the number of problems that can be addressed solely by quantitative analysis. Although conclusions drawn in the absence of quantitative measurement will have doubtful validity, action taken solely on the basis of quantifiable variables may lead to inappropriate, wasteful, noneffective, or undesirable results (Krone 1980). Fortunately, the choice is not an either or one, but one of sensible use of both quantitative and qualitative tools.

Qualitative variables can be used to evaluate system effectiveness in achieving system goals. They can be positive or negative depending upon whether they lead to system improvement or deterioration. If their influence is toward improvement, we would like to know more about the functioning of these variables, so the process can be countinued, expanded, and duplicated in other systems. If the influence is toward deterioration, we want a capability for identification, evaluation, and rectification before system failure becomes irreversible.

A NEW PARADIGM WITH TECHNOLOGY ENDOGENOUS

Modeling of the forest economy should use an evolutionary approach to economic growth and development in which technological change is incorporated in the theoretical basis of systems operation as suggested by Nelson and Winter (1973). Their objective is "to develop a theory of the firm, the sector, and the evolution of economic capabilities that is consistent both with detailed historical analysis and with observed patterns of aggregate data." This might be called the economic history approach (Dunn 1971). It is particularly relevant when long-term analysis and projections of 10 to 50 years or more are considered as in the case of many forest sector analyses. Noble prize winner, Simon Kuznets (1973), observes that advancing technology is generally the main source of economic growth for most countries. But, in order for new technology to be employed efficiently and widely, institutional and ideological adjustments must be made to affect the proper use of innovation. As such, it does represent the dynamics of the evolution of technology and economic change through time (Rosenberg 1976).

The economic theory selected will be somewhat at variance with the traditional neoclassical theory that is widely used in economic analysis. The neoclassical concept to technology views technology as represented by production functions that relate input factors to output. Changes in the production process are determined by factor substitution and relative price ratio. Ayres (1988) describes the shortcomings of neoclassical theory and the need for the alternative technology approach and concludes:

> The major conclusion of this paper is the most straightforward implication of the fact that wealth is (mainly) derived from technological innovation. It is that a better theory to explain the various processes--invention, innovation, investment in risky ventures, adoption of new technologies and new products, institutional learning, and so forth--is urgent. The

specific effects of particular policies and the overall impact of the policy environment as a whole on innovation and technological progress deserve vastly more attention than they have received in recent years.

Technology is one of the most important forces in the value of an industrial sector. Industrial development is largely determined by technology and resource availability to meet demand (Rosenberg 1982). This paper suggests an approach or a scientific paradigm that incorporates technology directly into the formal analysis procedure or model. The system may also be in a state of disequilibrium as is the case in the real world (Benassy 1982, Cuddington et al. 1984). Furthermore, it has been shown that nonlinear dynamic economic systems can exhibit chaotic or unstable behavior and never achieve stable equilibrium (Brock 1988).

This paper provides some considerations for an alternative view of forest sector modeling to general or partial equilibrium analysis. The salient feature of this approach is the view of the forest sector as a system. The general systems concept is characterized by consideration of the system as a whole and the emphasis of systems performance variables for measurement of the system state. The systems concept of technology is an integral part of this approach. Technology is a keystone to long-term resource development.

THE SYSTEMS VIEW OF TECHNOLOGY

The systems view of technology has many advantages. The functional measure of technology provides clear meaning for variables and can be objectively measured. Technology performance should be expressed by functional measures of performance rather than some nebulous variable, such as capital in a neoclassical production function. Both major and minor innovations in technology can be represented in the production process. Constraints and related systems performance can be related by the use of functional systems measures. Changes in product types and characteristics are also easily represented in the systems approach. In summary, as Sahal (1978) observes: "the functional view of technology may well be a prerequisite to an adequate understanding of a variety of interrelated problem areas and policy issues." Thus, the systems concept of technology has advantages over both the classical production function and the Pythagorean accounting method of listing prospective new technologies.

This paper proposes an evolutionary approach to the economic process and the systems view of technology. Thus technology should be viewed as evolving within the systems constraints guided by various economic, social, political, as well as technical variables (David 1975). Concepts of system scale and growth of subsystems are also important. The evolution of systems generally involves the disproportionate growth of subsystems and increases the complexity of the system. The concept of creative symbiosis in which two or more technologies combine in an integrated fashion such that the overall system is greatly simplified is also important. This eliminates obstacles or negative salients to further evololution. Thus, when this occurs, new possibilities emerge for production possibilities and technological progress. This leads to the following proposition by Sahal (1978) for a general thesis of the evolutionary processes:

1. Short-term evolution is a process of equilibrium governed by the dynamics of the object system.

2. Long-term evolution is a process of disequilibrium governed by the dynamics of the whole system.

Spatial equilibrium analysis is consistent with the short-term evolution concept. Markets may tend toward short-term spatial equilibrium, while being in a state of long-term disequilibrium because of technology change or other structural economic changes in the larger economy. Innovation leads to alternative paths of economic development which change the existing market equilibrium. New innovations often spawn other innovations and lead to further economic growth which is not wholely predictable (Schumpeter 1934, 1939).

Investment in new production plants and equipment is also important in determining temporal equilibrium conditions. An enlightened view of production functions that includes dynamic aspects of capital investment, technology, and capacity change is provided by Johansen (1972). He argues that use of constant elasticities of demand and supply through time is meaningless even if they could be measured: "the approach taken by the present study is rather to ask if it is at all meaningful to talk about 'actual elasticities' in this way as something unique which we could try to reveal by various types of data. It may well be that we should get different estimates by different types of data, these different estimates reflecting different aspects of a more complex technological structure than that described by traditional production functions." Johansen further states that it is impossible to estimate long-run macro level elasticities from short-term annual data. The essence of his approach is to construct short-run and long-run micro and macro production functions that include a technological and capacity component. He concludes that "our standard short-run macro function represent short-run equilibrium positions, whereas actual observations usually represent some degree of deviation from equilibrium."

There are two main propositions of the theory of resource development and technological change advanced here. First, the long-term evolution of technology is governed by the accumulation of experience of a practical nature. Second, the technology of a system is a function of the scale of application. The starting point of a technology is the well-known concept of the progress function--that the production of a plant gradually increases as it becomes possible to remedy various bottlenecks of accumulated experience. These two basic considerations are particularly important in the governing of a dynamic system of technology change and are related to its history and scale.

Trends toward increased complexity in systems may very well be balanced by the concept of creative symbiosis. That is, while the evolution of a subsystem may be moving toward more complexity, the whole system may be moving toward simplicity. In the case of forest products, production functions may be moving toward greater integration of nonwood factors of production, as in the case of lumber compared to plywood, and compared to waferboard.

Two major implications of the theory are presented here. First, hitherto socioeconomic systems have been conceived in terms of exogenously governed homeostatic systems that return to constant state after temporary perturbation. That is, the processes of socioeconomic change eventually reach a state of equilibrium. According to the viewpoint advanced here, however, an appropriate formulation of socioeconomic systems is in terms of endogenously governed homeodynamic systems capable of seeking new paths of evolution through successive instabilities. Some instability is caused by technology change. That is, the processes of socioeconomic change remain in a constant state of disequilibrium. To put it differently, the traditional viewpoint is solely concerned with the mechanism of change. In contrast, the focus of the proposed viewpoint is on the organism involved in change. Second, a cardinal feature of the contemporary approach to modeling of the socioeconomic process is that their course is completely determined by the present or expected value of the relevant variables. According to Sahal (1978), gross (cumulative) investment is a key determinant of technical progress in industrial development. This suggests socioeconomic change is most clearly influenced by cumulative change of a systemic nature. In this paradigm of technological progress, research is particularly important because its impact is cumulative and may not be felt for a long period of time. This paradigm suggests the value of forest resources and how the competitive position of the forest sector can be enhanced by a technological development of the biological or physical resource. Future demand is indeterminate in that it is dependent on the investment in research on forest utilization and biological growth enhancement. Utilization improvements have the added advantage of immediately impacting on the forest economy.

The progress function is appropriately viewed as a model of improvement in the productivity of any system embodying a given technology. Thus, there is generally a significant process of learning in the use of an existing technology over time. The thesis presented here is that there are other learning processes underlying the development of new techniques in the first place. In particular, it is assumed that the fruition of technical advances invariably depends on the accumulation of production experience. Quite often in the innovation process there is a period of deadlock of progress because of lack of some critical element or related technology or some institutional constraint. For example, Babbage had already developed an "analytical engine" that had the essential elements of the modern computer in 1833, but it wasn't until the development of the transistor in the 1950s that the computer age was born. This indicates that many contemporary advances in technology are based on prolonged development efforts. A great deal of technical progress is made through the gradual refinement of certain basic patterns of design. Even potential major innovations must undergo extensive modifications before their potential can be exploited. This suggests what might be called the "learn by doing" hypothesis of technological innovation. The evolution of technology is not merely an outcome of a set of replicative events at work. Rather, it is governed by a process of cumulative change. To measure experience we must measure a certain activity over time. Experience with a particular technology can be measured in terms of years of production or accumulated output.

Product innovations often depend on sucessful changes in production techniques. The origin of productive know-how is based upon productive experience. Once the the relevant know-how is generated, its successful adaptation is again a function of learning in the production activity. The reason is that product and process technology constitute an integrated system, so that one cannot be changed independent of the other. Moreover, the mutual dependence between the two generally grows stronger over the course of time. Thus, successful assimilation of technical know-how is also a matter of experience acquired in the productive process. Also, while experience plays a central role in the process of technological innovation, the benefits from increased know-how can seldom be obtained as soon as the knowledge is acquired.

Technology, socioeconomic, and resource systems are all interrelated. Technology and social systems interact with each other into what Bijker et al. (1987) call "the seamless web character of technology and society." They note "system builders are no respecters of knowledge or professional boundaries." They refuse to distinguish between micro and macro analysis. Successful systems builders (such as the growth of the United States electric supply system) simultaneously had to engineer technical matters (such as the design of an electric lamp filament), economic matters (such as to compete in price terms with existing gas suppliers), and political matters (such as the legislative frameworks when electric supply was developed). Similarly, the the forest sector should be analyzed based upon considerations of its resource, technological, and market systems that are embedded in the larger technological, socioeconomic, and political systems of society as a whole.

CONCLUSIONS

The concept of the forest and forest product sector as a system as explicated by Duerr et al. (1979) is useful here. They state:

> A major aim is to focus the work upon integrated forestry: the creation and use of all forest values from scenery to wood. We have tried to see forestry as a system of interacting variables and also as a part of a larger social system that in the final analysis is the sum of human experience. Another aim is to view forestry not as a set of rules, but as a set of resource alternatives. Still another is to demonstrate how modern quantitative methods of generating information can fortify judgement in choosing among resource alternatives.

Systems analysis provides a way to look at forest resource economics and development to broaden the perspective of management decision making by considering factors other than the resource base. Technological changes occur over long periods of time. These technological changes influence wood utilization efficiencies. The rate of technological change in turn can be affected by forest products research efforts. The evolutionary approach to economic growth is particularly appropriate when time horizons are 10 years or more. Changes in technological, social, and institutional factors can become influences on resource development and the evolution of the forest resource sector.

Forest resources, product conversion technology, and market and consumption are all part of one interrelated system that exists in the social, economic, and political environment of a society as a whole. Most forest sector models, analysis and planning systems are resource driven. They should be driven equally by technology and conversion subsystems and market and consumption subsystems. These subsystems may be changed by research or technical development. The resource system is also modified by cultural activities, environmental change, and other biological factors. Capital investment and prospective future investment also are important factors. Thus this paper suggests the development of a dynamic spatial forest sector system for analysis with a technological endogenous subsystem that is based on sound basic premises.

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