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A Forest Sector Prototype Model - The Simplified Model Structure

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A FOREST SECTOR PROTOTYPE MODEL
— THE SIMPLIFIED MODEL STRUCTURE

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FOREWORD

The objective of the Forest Sector Project at IIASA is to study long-term development alternatives for the forest sector on a global basis. The emphasis in the Project is on issues of major relevance to industrial and governmental policy makers in different regions of the world who are responsible for forestry policy, forest industrial strategy, and related trade policies.

The key elements of structural change in the forest industry are related to a variety of issues concerning demand, supply, and international trade of wood products. Such issues include the development of the global economy and population, new wood products and substitution for wood products, future supply of roundwood and alternative fiber sources, technology development for forestry and industry, pollution regulations, cost competitiveness, tariffs and non-tariff trade barriers, etc. The aim of the Project is to analyze the consequences of future expectations and assumptions concerning such substantive issues.

The research program of the Project includes an aggregated analysis of long-term development of international trade in wood products, and thereby analysis of the development of wood resources, forest industrial production and demand in different world regions. The other main research activity is a detailed analysis of the forest sector in individual countries. Research on these mutually supporting topics is carried out simultaneously in collaboration between IIASA and the collaborating institutions of the Project.

This paper presents a non-technical discussion of issues relevant for analyzing long-term development of a national (regional) forest sector. Sectors and their interactions as related to forest biology, forestry management, roundwood market, wood processing, governmental regulation and consumption of world products have been discussed. This analysis serves as a basis for constructing a simulation approach for detailed forest sectorial analysis. This approach, called the Forest Sector Prototype Model, is the subject of a companion paper.

Markku Kallio
Project Leader
Forest Sector Project

ABSTRACT

This paper concentrates on a verbal and graphical description of the main elements and their linkages, of a prototype model which has been developed within IIASA's Forest Sector Project. This description creates the base for a computer model.

The model consists of two forest sectors —one for the national forest sector which is being studied and one for competing forest sectors. Each forest sector covers all activities from timber growth to the consumption of end products as well as economic, technological, biological, and human aspects. The sector is built up by eight submodels or modules concerning 1) demand, 2) product market, 3) forest industry, 4) roundwood market, 5) forest management, 6) inventory of standing volume, 7) regulation of the forest sector, and 8) construction sector. In the product market, price and actual demand for forest industrial products (pulp, sawnwood, and panels) are defined depending on domestic demand and supply as well as import and export opportunities. The same is done in the roundwood market module but for roundwood. Supply of forest industry products is defined in the forest industry module as well as demand for wood raw material. Supply of wood raw material is calculated in the forest management module. The inventory module keeps track of the biological possibilities for supplying roundwood. Investments in new industrial capacity and harvesting capacity can be regulatd through the regulation module. The capital sector module defines investment costs and efficiency (output/input ratio). The feedback mechanisms between modules is important in the model structure, as well as inside individual modules. Exogenous variables are GDP, size of population, prices of substitutes, exchange rate, prices of input factors, and technological development.

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A FOREST SECTOR PROTOTYPE MODEL —THE SIMPLIFIED MODEL STRUCTURE

Lars Lönnstedt

1. INTRODUCTION

The physical and institutional conditions vary from one country to another. A prototype model such as the one developed within IIASA's Forest Sector Project must be general and flexible, in order to be able to serve as a framework for national forest sector models (Adams et al. 1982, Grossmann et al. 1981). To meet this requirement the presented prototype model consists of a collection of submodels or modules. For a specific nation a set of modules applicable to the conditions of that country must be selected and linked together. A prototype model, that is used by picking up relevant submodels, can only be a starting point for analyzing problems within a nation. This kind of model is especially valuable for research teams lacking experience in forest sector modeling (Demand, Supply and Trade Group 1982a). The final national forest sector model will presumably be much more comprehensive than any prototype model (see for example, Ban et al. 1982).

The following modules are presented in this paper: demand for forest industrial products, product market, forest industry, roundwood market, forest management, inventory of standing volume, construction sector and regulation of the forest sector. When outlining the structure of the modules we have relied on managerial and microeconomic theory (for example, Douglas 1979, Gold 1971, Lyard and Walters, 1978 Cohen and Cyert 1965).

The modules of the prototype model are shown in Figure 1. (A detailed specification of the linkage between the modules and exogenous variables can be find in an appendix.) As can be seen from Figure 1 we, in this model, exclude modules of economic activities outside the forest sector (general economy, population, labor, energy demand) as well as modules of land use, pollution and regional demand (for a description of this type of modules see Grossmann 1982). The influence of these activities on the forest sector is exogenous.

2. DEMAND FOR FOREST INDUSTRIAL PRODUCTS

Many factors affects demand of forest products (see for example, Demand, Supply and Trade Group 1982b, Buongiorno 1978, Adams 1977). Changes in the prices will, given that other things are constant, change the quantities in demand. An increase in income will normally increase the amount of goods one is willing to buy. Quantity of forest products also changes as a result of changes in prices of other goods. A change in attitude to forest industrial products also affects demand. Even if consumption per person remains the same, a growth in population will increase the total demand for forest product.

The demand module determines and gives to the product market module the long-term development of domestic demand for sawn wood, wood-based panels, pulp (paper), and fuelwood. As indicated by Figure 2, the long-term demand for each type of product is calculated from demand per capita and size of population. Demand per capita is influenced by a) GDP per capita, and b) price of forest products relative to the prices of the substitutes (defined as substitution affect). Price of forest products comes from the product market module. The other variables are exogenous.

3. PRODUCT MARKET

In a perfectly competitive market the equilibrium price yield an equal supply and demand curve (see for example, Scherer 1980). Any price below the equilibrium creates an excess demand which encourages a price increase, thereby restoring equilibrium. Similarly, an adjustment process exists for prices above the equilibrium.

However, in the real world a perfectly competitive market does not exist. Producers do not know precisely when consumer tastes or prices of substitutes will change. Therefore, excess supply appears for some products, and excess demand, to others. By the time the producers have gained information on this the situation may have changed again. Another reason for not finding a perfectly competitive market is that many producers do not know which production technologies are used by others.

Monopolistic elements often distort competitive markets in the real world. One of the basic reasons for a monopoly is the economics of large scale production. This is especially true in a dynamic world of technological change. In many fields competition between numerous producers would simply not be lasting or efficient. Trademarks, patents, and

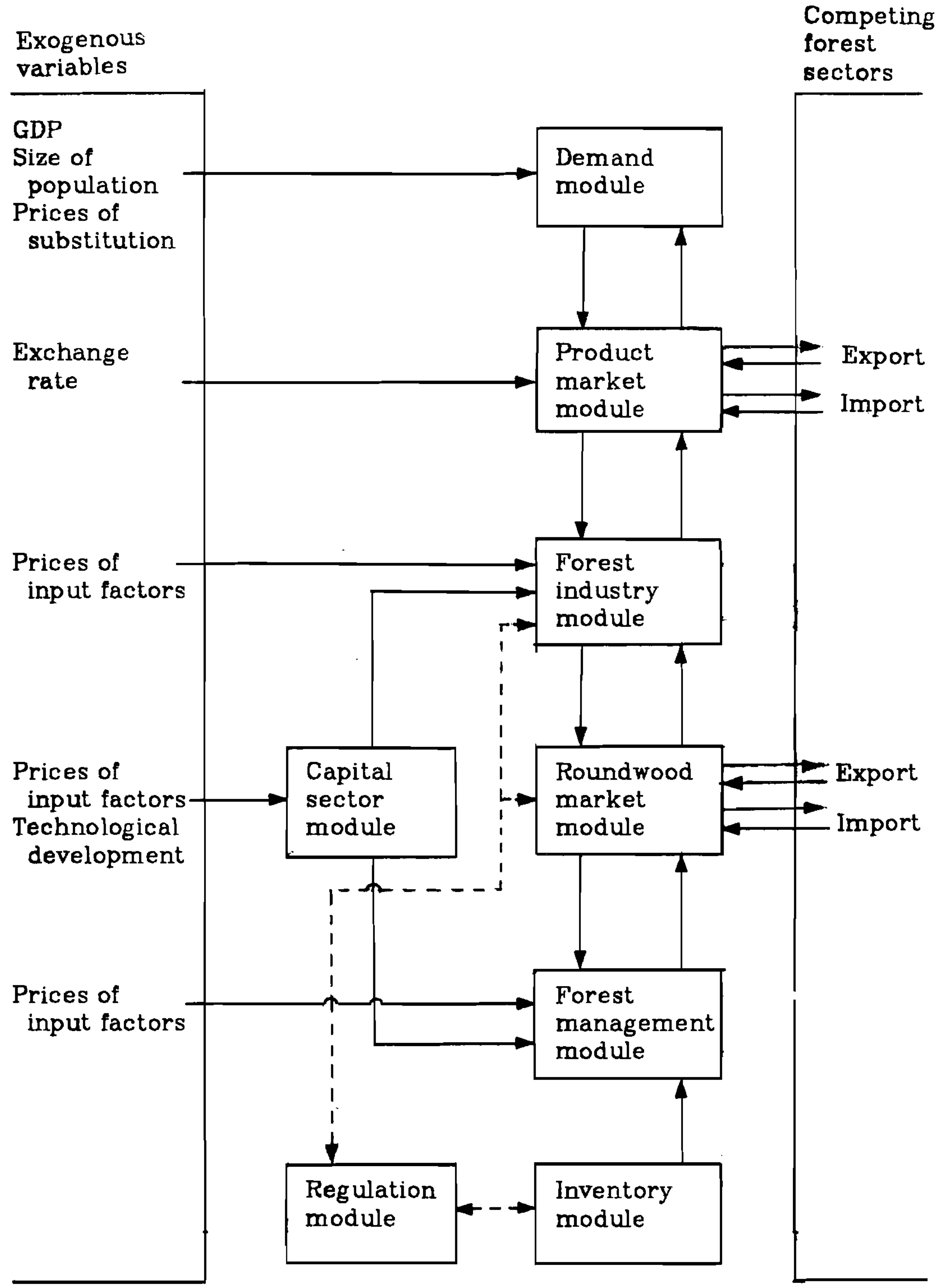

Figure 1. Outline of the prototype model and its eight modules. The linkage between the modules consists essentially of price and quality information. The regulation module specifies quantitative restrictions.

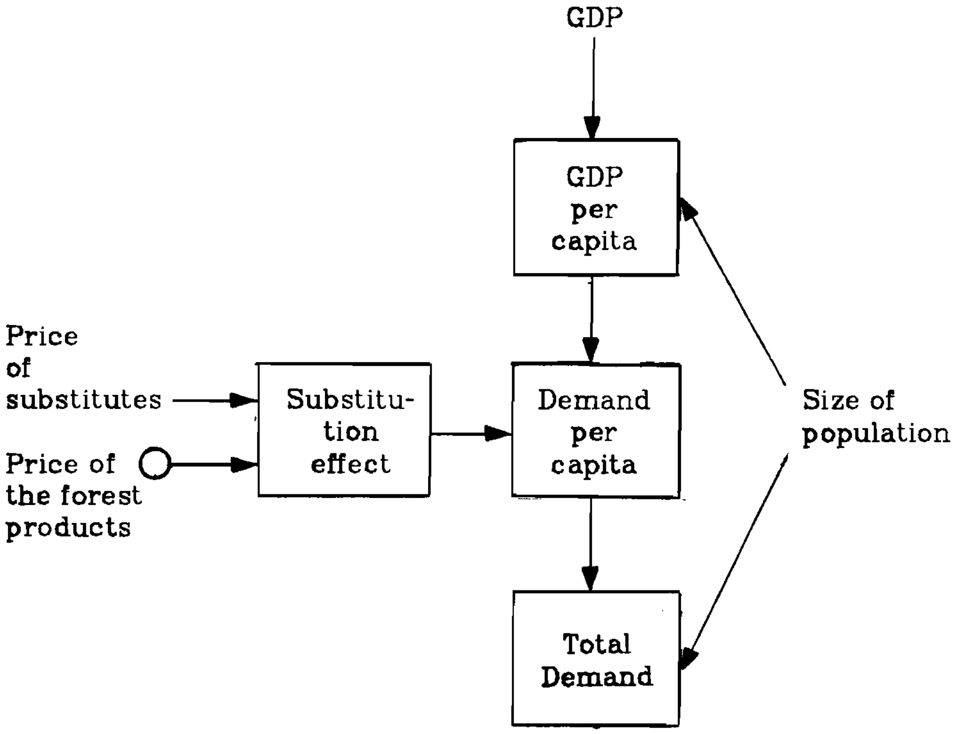

Figure 2. Structure of the demand module. (Arrows from a circle or box indicate that this information is received from another module. The other type of arrows indicate externally given information).

advertising are often responsible for other market imperfections.

Sawnwood, panels, and pulp can be considered as bulk products which prices are determined by the conditions on the world market. Given demand from the demand module and demand from other regions, supply from the industrial module and supply from other regions, the market module calculates actual demand and price of forest products which is passed back to the above-mentioned modules in the individual countries. The price that is settled for a specific time period will generate potential demand or potential supply. The difference between potential demand and supply is defined as the market imbalance and is passed on to the industrial module. If potential demand is greater than potential supply, the actual demand (consumption) is equal to potential supply. If it is the other way around, the actual demand will be equal to potential demand. Because of our interest in the long-term development we can ignore short-term fluctuations in production. Potential production is determined by capacity.

4. FOREST INDUSTRY

The overall goal of the forest industry, in the model, is to grow at the same rate as the market. As a criterion of success a minimum acceptable profit level has been chosen. The forest industry tries to meet this satisfactory profit level – a level that in the long run is determined by alternative investment opportunities. Two restrictions for the forest industry in the long run are sustainable yield of wood and the possibility to import wood raw material from other regions.

Three submodules can be recognized within the forest industry module (Figure 3):

- profit module
- cash flow module
- production capacity module

The forest industry module calculates and gives the supply of products to the product market module and to other regions. Demand for wood is calculated and passed on to the roundwood market and forestry management modules. Prices of the products and market imbalance – the difference between potential demand and supply – comes from the market module. The market imbalance affects the investments in new capacity. Excess supply means that planned investments are reduced and excess demand has the opposite affect. Roundwood prices, actual supply of wood, and timber balance comes from the roundwood market module. The capital sector module gives information abut the investment cost for new capacity and efficiency of new capacity. The regulation module gives information about recommended increase of capacity. Exogenously given are prices of input factors other than roundwood.

4.1 Gross Profit

Figure 4 illustrates definition of the gross profit of the forest industry.

Gross profit is calculated by subtracting all variable costs from the income of the operation (Horngren 1981). The income is determined by the price of the product and quantity sold. For exports exchange rates are taken into consideration.

Variable costs per produced unit are dependent on the efficiency in utilization of the input factors (amount of input factors needed per unit of output) and the unit cost of those input factors. The efficiency will in the short run be affected by maintenance investment and in the long run by investment in new equipment as well as shutdowns. The unit cost of an input factor can be at least partly affected by the alternatives between supplies and inputs. For example, a pulpmill can choose to a certain degree between chips and roundwood or between domestic and imported wood.

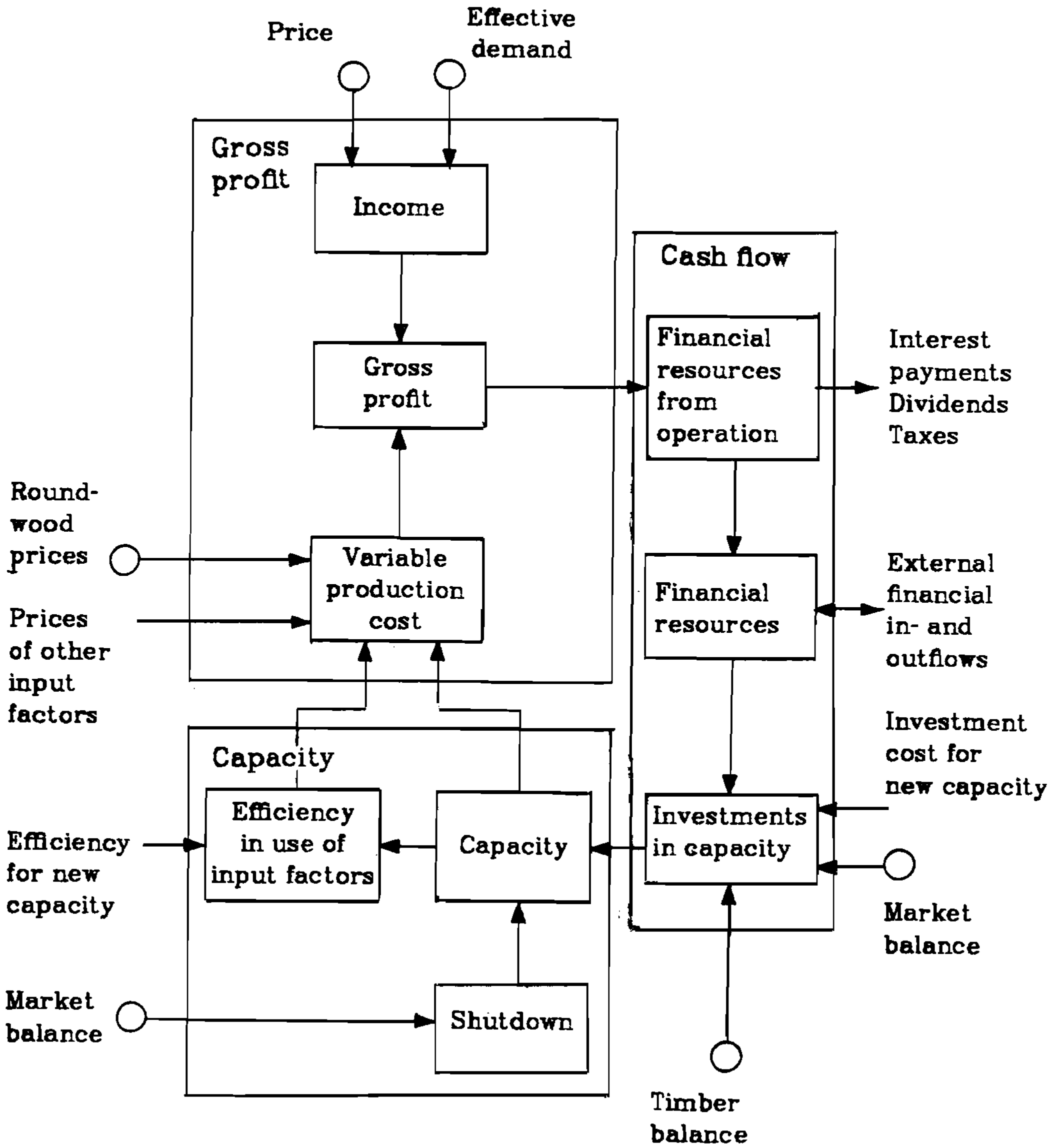

Figure 3. Structure of the forest industry module.

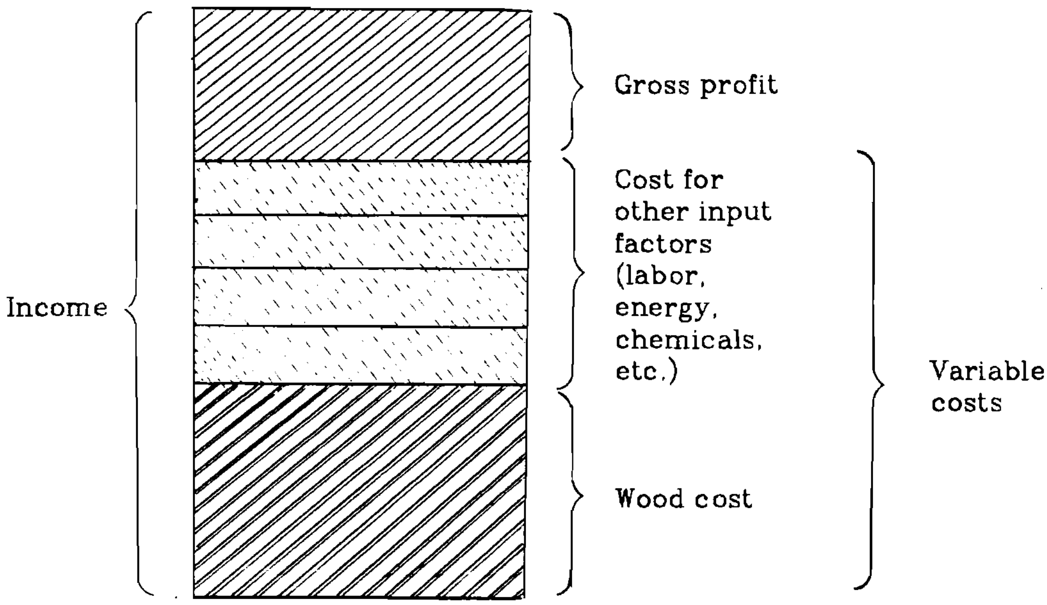

Figure 4. Gross profit, income and costs for forest industry.

4.2 Cash Flow

Figure 5 shows a general outline of cash flow* (see for example, Kallio 1977, Hunt and Kavesh 1976, Jaedicke and Sprouse 1965). Inputs to the cash flow are gross profits, new loans and selling of new shares. The net affect of changes in current receivables, current liabilities, or inventories can be an inflow or outflow of money. The following outflows from the cash flow is distinguished:

a) net interest paid

b) dividends to share holders

c) taxes

d) repayments

e) investments

f) net increase in working capital**

Investments in property and equipment usually represent the major outflow. The share of the investment outflow used for investments inside the forest sector can, for example, be related to the profitability of new forest sector investment opportunities. The same principle can be used for inflows from new loans, bonds, and shares. It is easier to raise funds if

* This is just one of several ways of observing a financial flow.

** Assuming no change in inventories, the effect of inflation can be neglected.

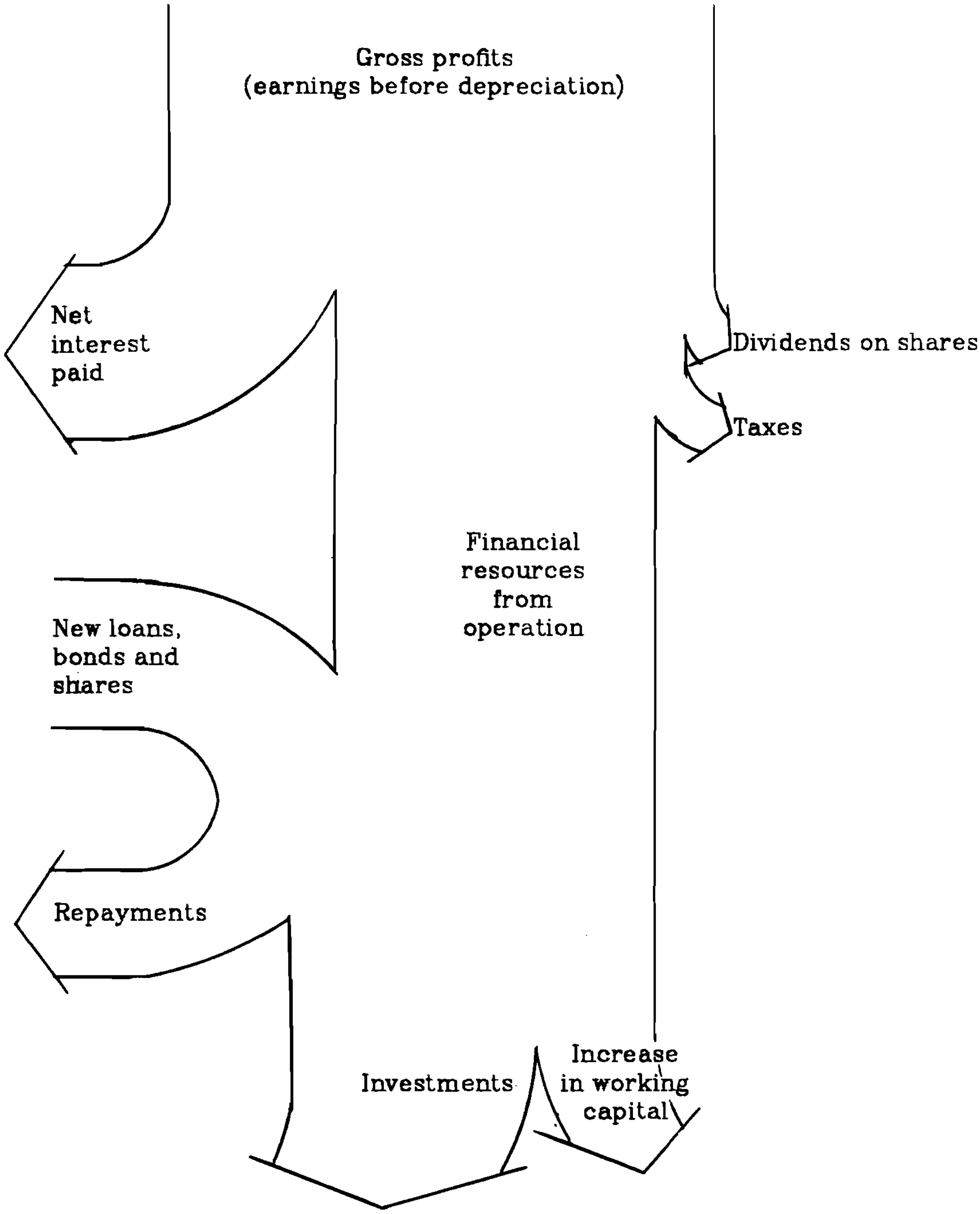

Figure 5. Cash flow

profitable investment alternatives can be offered. Other outflows are investments in shares and bonds, cash, and short term investments.

4.3 Production Capacity*

To invest in new capacity is a strategic decision (Eisner 1978, Manne 1967). When the investment is made the capacity follows a life cycle. The length of the life cycle depends on the maintenance and technological development (production efficiency of new capacity). The latter also affects the product prices. The older the production equipment the higher the unit production cost and the lower the gross profit. There also exist a tendency towards increasing unit production cost for capacity just to be invested due to shortage of supply of input factors. In Figure 6 we present a general outline of the life cycle (Johansson and Strömqvist 1980, Johansen 1972).

Even if there is a connection between age and shutdown it is not straightforward. Through maintenance and supplementary investments it is possible to modernize existing capacity, i.e., to move old capacity to the beginning of the cycle. In special cases a company can buy a

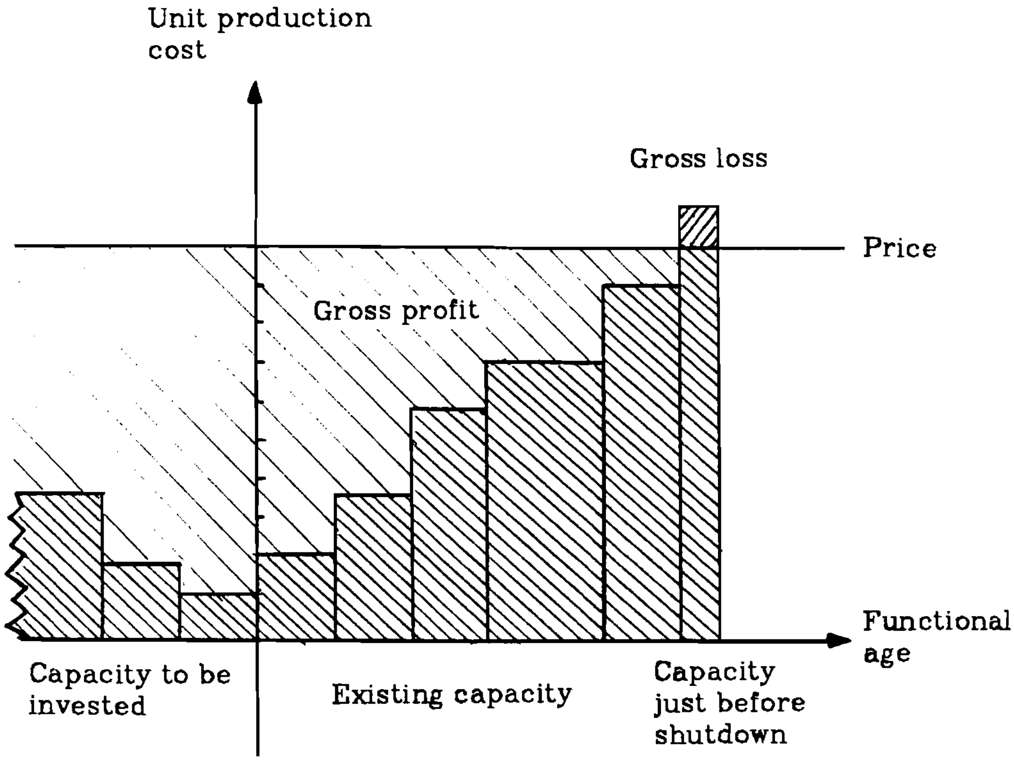

Figure 6. General outline of the life cycle of capacity.

* Here capacity is defined as that quantity of the product that in the long-run could be produced per year with normal use of equipment.

profitable mill and close it if this will allow the buyer to control the price and in this way increase his profit. In the same way it can take some time before an unprofitable unit is shut down: the company may wait for better prices. Labor unions and politicians often oppose closure of a production unit, especially if this is the only main production in a village.

The capacity level in the module depends on investments and shutdowns as well (see Figure 3.) These two variables, through the degree of obsolescence of the equipment, affect the efficiency of factor use, which, together with the prices of the input factors, determine the unit production cost. The level of investments depends on the funds available for new investments in capacity and the costs of this new capacity. The funds available for investments depend, as mentioned, on the cash flow but also on the market situation. The closure rate reflects the life cycle of the capacity. For how long capacity will be used depends on physical deterioration as well as economic conditions.

The production is supplied to the domestic market as well as to other regions.

5. ROUNDWOOD MARKET

Figure 7 outlines flow of biomass within and out of the forest.

Biomass is defined as the total amount of organisms (or organisms belonging to particular species or groups of species) within a delimited area at a certain time. Total drain is the stem volume of all trees that have been felled and trees that have died and are left. Total wood deliveries are calculated from total drain through subtracting different kinds of losses and residues. Logging residues are whole stems or parts of stems that are not collected. Losses in logging are wood raw materials, other than residues, that are lost in the cutting area. Losses in transportation are wood raw materials lost during transportation. How much wood that will be available for industrial use and for fuelwood besides the total wood deliveries depends on export and import of wood.

The forest industry and forest owners are regarded as two independent parties in the module. The roundwood market is characterized by bilateral monopoly. In this kind of market situation the actual price is somewhere between the optimal price for the seller and buyer, respectively. Exactly where depends on several factors as negotiation capacity and negotiation power.

In principle there are two types of timber purchases: as delivered sales and as standing timber. Influenced by the demand for forest industry products, costs, and the market situation, the delivery price is agreed by forest owners and forest industry managers. The price of standing timber is, in principle, negotiated for each purchase between the seller and the buyer. This negotiation is affected by the delivery price for timber, by logging costs, tending cost, soil rent, and capital cost. Only delivery prices are considered in this module.

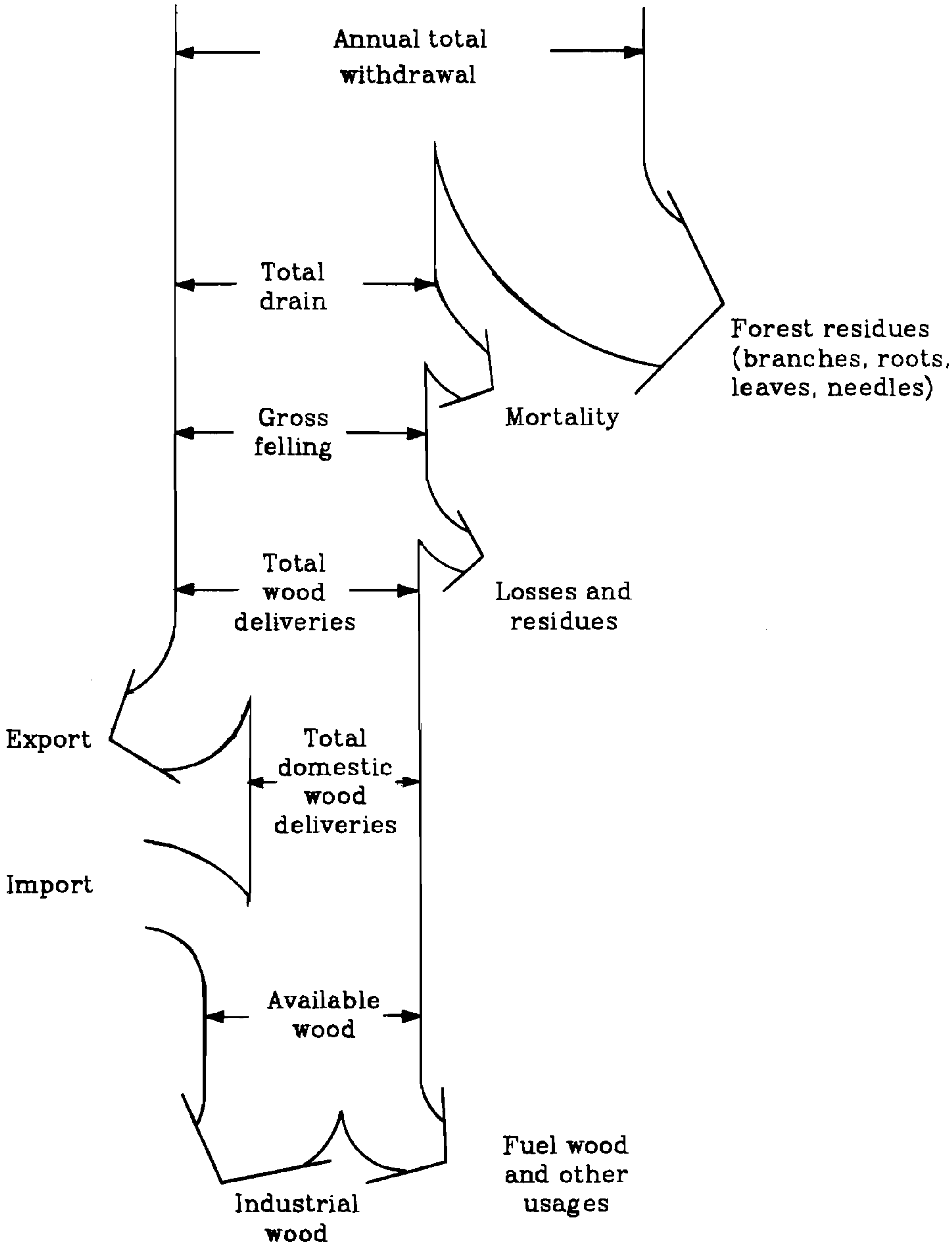

Figure 7. A diagramatic outline of the physical flow of fibers and used concepts.

Given the demand of wood from the forest industry module, supply from other regions, domestic supply of wood and the negotiating powers of the sellers and buyers, delivery price and actual supply are calculated in the roundwood market module and passed on to the forest industry and forest management modules. Negotiating power for industry and forestry is assumed to be affected by potential demand and long-term sustainable yield, respectively. The negotiation power of the forest owners increases with increasing shortage of wood.

The relationship between potential domestic demand of wood and sustainable yield, called timber balance, is calculated and passed on to the regulation module where it affects the regulation power.

6. FOREST MANAGEMENT

A presumed long-term goal of forest managers is to adjust the harvesting capacity to the industrial capacity, taking economic and biological restrictions into consideration. As for the forest industry module three submodules are distinguished: a) stumpage price, b) cash flow, and c) harvesting capacity (Duerr et al. 1979, Gregory 1972, and Johnston et al. 1967).

The forest management module gives supply of wood to the wood market module and to other regions. The harvesting cost increases with the utilization of the forest resources because the quality of stands deteriorates and the average distance between delivery sites and mills increases. As a measure of the utilization of the forest resources, the timber balance is used. From the roundwood market module delivery price and actual demand are given. From the forest industry module, capacity which affects the decision about investment and capacity utilization in forestry is given. The capital sector module gives information about investment costs for new capacity and efficiency of new capacity. The exogenous variables are the same as for the industrial module: prices of input factors.

6.1 Stumpage Price

Figure 8 illustrates definition of stumpage price in forest management.

Income from forestry is determined by delivery price multiplied by total deliveries. Variable costs are costs for logging, off-road extraction, and associated administration. The stumpage price reflects forest management activities from seeding and to ct, rotation period, and also the market situation. Forest management directed towards mining as in some parts of South East Asia requires no or low stumpage price compared with a sustainable forest management regime as in Scandinavia. Investments in silvicultural activities have a much shorter pay off time due to shorter period in tropical regions than in the northern regions. Stumpage price, which in the model will be used as a profit measure, is calculated by subtracting the variable costs from the income.

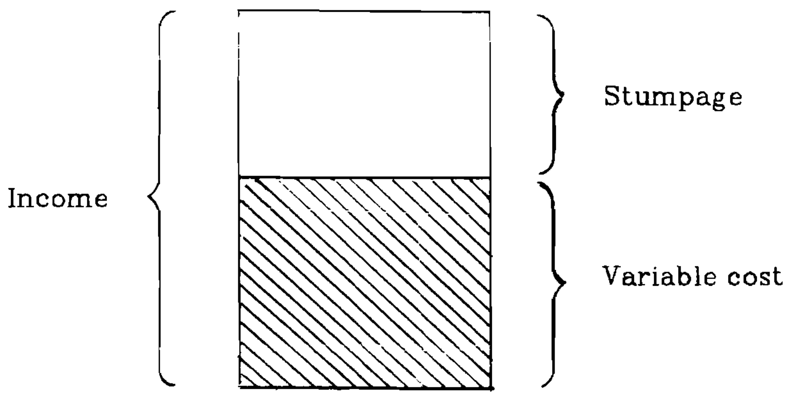

Figure 8. Stumpage, income, and costs for forest management.

In some countries, the high stumpage prices within forestry compared with the gross profit of the forest industry or other production activities can be explained by the long rotation, which means that money invested in a forest will be bound for a very long period.

6.2 Cash Flow

The inflow to and outflow from the cash flow follows the same principles as for the cash flows of the forest industry (compare Figure 5). The size of the flows, both absolute and relative, is however quite different. One explanation, at least for some countries is that the non-industrial forest owners are not represented by any firm but rather by a group of individual citizens. The forest is a source of income for them and for some a working place.

The type of investments that are made can be divided into three groups:

a) infrastructure
b) machines
c) silvicultural activities

The main part of investments in infra structure consists of building new roads and improving old ones. Lack of or a poor infrastructure is a substantial drawback for some countries that want to build up a forest sector (for example Brazil) in comparison with countries with a mature forest sector (for example Finland). The investments needed sum up to big amounts which are difficult to finance from a limited domestic capital market. A capital market that also has to supply many for other more profitable and needed investments.

Silvicultural investments are made to clean clear felled areas, to scarify the soil, including controlled burning, to artificially regenerate, to fertilize, and to drain the forest land. In this respect cleaning and control of young hardwood are looked upon as maintenance measures. It is easy for most forest owners to finance such investments if they have an even age distribution of the forest. The main part of the stumpage price is a return for the investments made.

6.3 Harvesting Capacity*

The harvesting capacity has as the industry capacity a life cycle which is affected by maintenance and replacement. This life cycle is, however, much shorter than for the industrial capacity. The consequences of scrapping logging machines are much less dramatic than those of closing a mill — because of a relatively small economic, public, or political interest. Flexible capacity utilization provides efficiency. An example of flexibility is that some forest owners use the work force and their machinery not only in the fields but also in the forest. Public and political interest can be directed against introducing new logging equipment. If implemented too quickly it can adversely affect the number of workers and the recreation value of the forests.

7. INVENTORY OF STANDING VOLUME

Some basic concepts in forest development are standing volume, increment, and total drain (Assmann 1970). The standing volume can be looked upon as an inventory that increases by increments and decreases by the total drain. Depending on the aim it can be of interest to specify those characteristics for different regions, forest owners, or species.

We define increment as the increase of the standing volume during a specified time span. There are several ways of measuring increment — we will be talking about increment as a percentage increase of the standing volume relative to the volume at the beginning of the time period.

The total increment of a stand or within an area depends upon the wood volume of forests — the more wood the more increment. Other factors are also of importance, which is obvious if we look at individual trees. There is a big discrepancy in increment between different species and different groups due to climate and soil. (The latter are measured by "site quality class"). The percentage increment is larger for a young tree than for an old one.

There are several ways for harvesting: clear cutting, thinning and cleaning. A clear cutting generates a big area for regeneration activities. Thinning produces some merchantable timber: at the same time it affects the growing of those trees that are left. Cleaning is an example of tending in order to improve the economic result. Silvicultural activities are one way in which man tries to generate more and better trees.

This module keeps track of the forest resource and calculates the resource base for the forest industry module. The standing volume increases with the annual increment and decreases due to harvesting and mortality (Figure 9). The increment has been made a function of density

* Here capacity is defined as the volume that, in the long run, could be harvested per year with normal use of equipment. labor, assuming full demand.

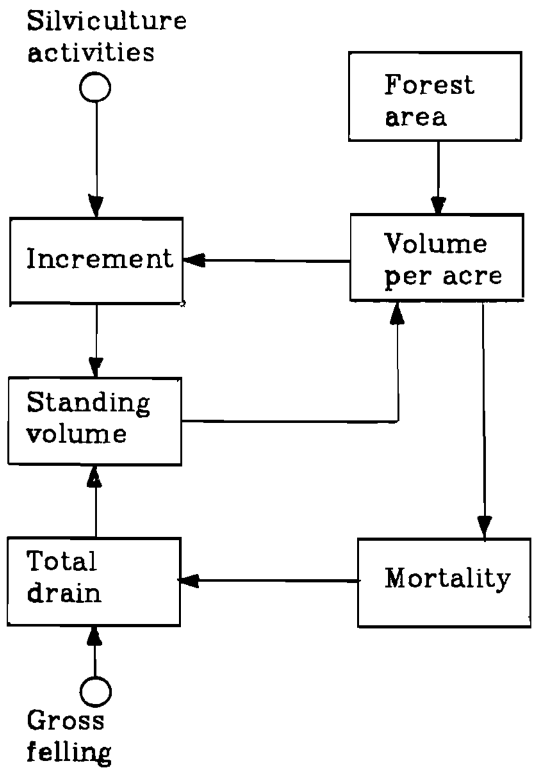

Figure 9. Structure of the forest module.

— the more volume per hectare, the lower the increment percentage. Mortality has also been made a function of density — the higher the density, the higher the mortability.

Total drain is calculated in this module and used in the roundwood market module from which comes actual supply of wood. Increment and standing volume are used inside the regulation module.

8. CONSTRUCTION SECTOR

The technological development in the forest sector is rather slow. Manufacturing technology is based on well-known principles and readily available machinery. It can be expected that within the forest industry, the success of a company and of the whole sector can only, to a very limited extent, be based on its own technological innovations. Technological development and innovations are world wide available.

Given the technological development, measured as amount of input factors needed per produced unit, and prices of input factors, this module determines investment cost and efficiency for new industry and harvesting capacity.

9. REGULATION OF THE FOREST SECTOR

In some regions, for example in Scandinavia, there are restrictions on the supply of wood as well as on investments in primary forest industry production due to a political decisions concerning long-term sustainable yield. The effectiveness of such regulation power for meeting the sustainability target varies. The regulation power can be assumed, for example, to increase the closer the gross fellings come to the sustainable yield. Sustainable yield is calculated by looking at the increment and standing timber — information about those variables comes from the inventory module.

For an existing industrial capacity, it is for reasons of employment politically difficult to justify a low-capacity utilization on ground of the long-term sustainable yield target. A regulation of industrial investments is easier to implement. The effect of the timber balance on the industrial investment decision can be seen as a political or a voluntary regulation.

10. CONCLUDING REMARKS

The method applied consists of building a prototype model consisting of a collection of submodels or modules. The problems, that the prototype model addresses are cost competitiveness and wood availability. The model is intended to be used for policy analysis (Grossmann and Lönnstedt 1983).

The modules presented in this paper are: demand for forest industrial products, product market, forest industry, roundwood market, forest management, inventory of standing volume, construction sector and regulation of the forest. In some cases, as for the sector. roundwood market module, there will be different structures of the module for different conditions, e.g., for industrialized nations and developing countries and for centrally planned economies and market economies.

For a detailed national model a specific set of modules applicable to that country will be selected. The prototype model will thus serve as a framework for detailed national models. A national model can be much more detailed than the prototype model.

Clearly, constructing modules should be directed towards a level of detail that allows reasonable separation of species and products important for different processes and uses. This type of disaggregation can be a long-term objective. We have found that only a stepwise approach is realistic. Using the stepwise approach, it is possible to guarantee that whatever the stage the study is at, there exists a functioning model; the degree of sophistication depending on the stage of development. Although early versions of a prototype model will serve mainly as vehicles for understanding the behavior of the system and demonstrating the functioning of the models, it can also be considered as a tool for higher level policy analysis.

The next step in the development of national forest sector models will be to formulate the structure of the prototype model in mathematical terms (Lönnstedt 1983).

APPENDIX 1: LINKAGES BETWEEN THE MODULES

(The diagonale indicates exogenous variables)

FROM \ TO	DEMAND	PRODUCT MARKET	FOREST INDUSTRY	ROUND WOOD MARKET	FOREST MANAGEMENT	INVENTORY	CONSTRUC-TION SECTOR	REGULATION
DEMAND	- GDP - Size of population - Prices of substitutes	- Potential demand						
PRODUCT MARKET	- Prices		- Prices - Actual demand - Market balance					
FOREST INDUSTRY		- Potential supply - Processing cost	- Price of input factors	- Potential demand of wood - Maximum stumpage share	- Potential demand of wood - Capacity			- Capacity
ROUND WOOD MARKET			- Delivery price - Actual supply of wood		- Delivery price - Actual demand - Indicated timber balance	- Actual supply		- Actual supply - Timber balance
FOREST MANAGEMENT				- Potential supply - Harvesting cost	- Prices of input factors			
INVETORY				- Total drain				- Increment - Standing volume
CONSTRUC-TION SECTOR			- Investment cost - Efficiency		- Investment cost - Efficiency		- Technological development - Prices of input factors	
REGULATION TION			- Recommended investment	- Sustainable yield				

APPENDIX 2: DEFINITIONS

Biomass:	Total amount of organisms (or organisms belonging to particular species or groups of species) within a delimited area at a certain time.
Efficiency:	Amount of factors need for producing one product unit.
Gross profit:	Variable costs subtracted from income of the operation.
Income:	Price of the product (respectively, delivery price) times quantity sold (respectively, deliveries).
Increment:	Increase of the standing volume during a specified time span.
Logging residues:	Whole stems or parts of stems that are not collected.
Losses in logging:	Wood raw materials other than residues, that are lost in the cutting area.
Losses in transportation:	Wood raw materials lost during transportation.
Module:	A building block — a submodel — of a prototype model.
Standing volume:	Inventory of standing wood.
Stumpage price:	Delivery price minus variable costs.
Substitution affect:	Forest product price relative to prices of substitutes.
Total drain:	Stem volume of all trees that have been harvested and trees that harvested and are left.
Total wood deliveries:	Total drain minus losses and residues.
Variable unit costs	Factor costs per unit divided by factors needed per unit.

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