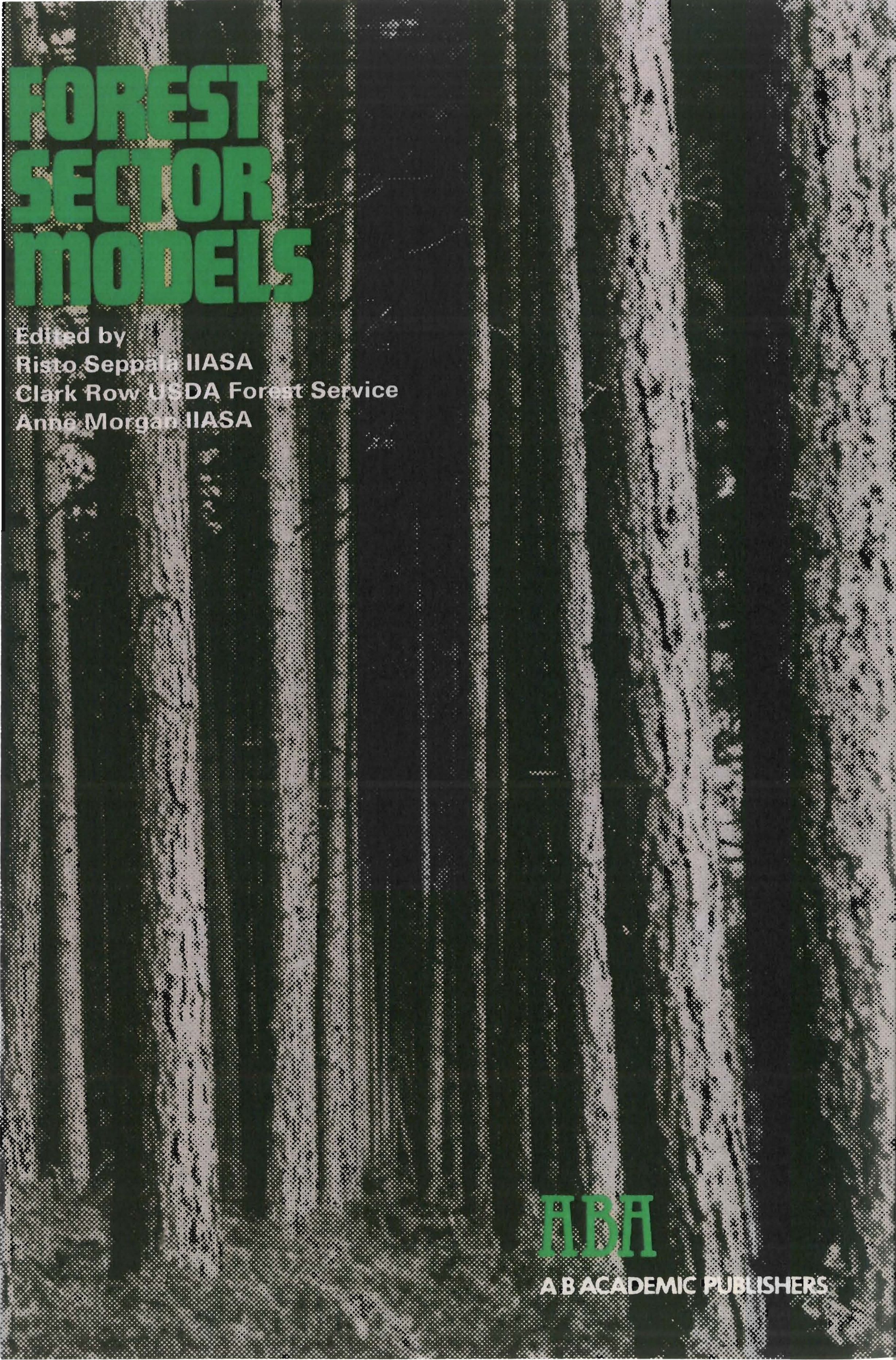

FOREST SECTOR MODELS

Edited by
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Clark Row USDA Forest Service
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Proceedings of the
First North American Conference

Edited by

Risto Seppälä, *IIASA*
Clark Row, *USDA Forest Service*
Anne Morgan, *IIASA*

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PREFACE

These proceedings of the NORTH AMERICAN CONFERENCE ON FOREST SECTOR MODELS represent not only individual contributions of some 40 researchers, but also significant progress of an unique international effort in forestry research: The Forest Sector Project of the International Institute for Applied Systems Analysis (IIASA). The project is a joint effort of researchers in over 15 nations to cooperatively develop models of their forest sectors that can be linked together to form an international model useful for projecting the development of resources, the progress of industry, and the flows of trade worldwide. Such linkage of models has never been attempted in forestry.

In the development of forest economics in North America, the concept of forest sector models is not new. Though the term "forest sector model" was seldom used, a number of models were developed conceptually, fitted to data, and used on a limited basis to gain insights into policy problems. Among the early research efforts were econometric models of William McKillop, Thomas Mills, Gerard Adams, and Darius Adams. Another approach, linear programming, was the basis for spatial models of Lester Holley, and Richard Haynes.

U.S. forest sector models were initially developed separately from the periodic assessments of U.S. timber resources conducted by the USDA Forest Services since the 1920's on roughly 10-year intervals. In the most recent USDA Forest Service assessment, however, substantial use of the "Timber Assessment Market Model" by Darius Adams and Richard Haynes, allowed improved projections of supply and demand, using the equilibrating role of price.

Canadian researchers have developed models of aspects of forest sectors. Among them are those used in the "Outlook for Timber Utilization in Canada to the year 2000" published in 1979 by the Canadian Forestry Service.

At the same time, a number of Scandinavian researchers were developing models of their forest sectors, which had several substantially different characteristics. In the Scandinavian models, more attention is given to product processing and interactions with the general economy, which recognize the relatively greater importance of forest products. One of the most widely known of these models was that of Jorgen Randers, which used a systems dynamics framework.

In 1979, new prospects for advances and coordination of research on forest sector models were raised by a study proposal of the International Institute for Applied Systems Analysis. IIASA was founded in 1972 by the academies of science or equivalent institutions in 12 countries, both East and West, primarily at the joint initiative of the U.S. and the U.S.S.R. The sponsoring academies, now 17 in number, had given IIASA the task of conducting and simulating research on complex problems of modern societies having international importance. In a relatively few years IIASA had developed a worldwide reputation in systems analysis and modeling methodology, and had made substantial progress in a number of applied areas.

IIASA selected forestry and forest industries as one of major industrial sectors to study. Suggested by Finland, the forest industry study initially sought to identify current and potential applications of management and information systems in the industry. Early meetings of the study, in January and November of 1980, discovered, however, that applications of systems analysis were far more extensive than anyone had thought. Of great importance was the experience in modeling and interest in applications concerned with entire forest sectors of an economy, long-run timber supply problems in various world forest regions, and international trade in forest products.

From the early meetings, and visits and discussions with various national groups, the IIASA staff formulated the general research approach now being pursued. In December 1980, members of the IIASA staff met in Washington, D.C., with representatives from the USDA Forest Service, U.S. forest industry, universities, and Canada. Forest industry and the Forest Service approved of the general approach and pledged support for the study in the form of funding assistance, in visits of U.S. scientists to IIASA for work and consultation, and in cooperative research at U.S. locations. The approach, modified according to comments received by the U.S. and other cooperating national groups, is discussed in the article by Risto Seppälä in this volume.

Part of the U.S. cooperation was agreement to jointly sponsor one of more conferences in North America on forest sector modeling. These proceedings are part of the results of the first of these conferences, held in Williamsburg, Virginia, December 1-3, 1981. The objectives of the conference were to:

1. Present to North American and worldwide researchers and policy analysts the current state-of-the-art of modeling forest sectors and their components.

2. Discuss new approaches to modeling aspects of forest sectors not currently used, but potentially useful and quantifiable in some countries or situations.

3. Develop further the organization, scope, and approaches of the United States and Canadian contributions to the IIASA Forest Sector Project.

The conference was divided into several broad topics. Within these topics the speakers covered a wide variety of aspects, including:

1. National forest sector models as integrating and equilibrating mechanisms of resource supply, product demand, processing industry, international and interregional trade, and national economic situations.

2. Forest resource and timber sectors, including both short-term supply of removals from various ownerships, and long-term changes in land use, timber growth, investment in management, technological change in forest management and harvesting, transport facilities, and public resource and environmental policies.

3. Forest product demand relationships (including both solid wood and pulp and paper products), and particularly the effects of demographic and economic factors, prices of products and substitutes, and technological

change in either forest products or substitutes.

4. Foreign trade in forest products, including the influence of barriers to free trade, transportation costs and institutional factors, exchange rates, and national foreign trade policies.

5. Development and shift of forest product manufacturing facilities, especially the role of factor costs (such as labor, energy, and capital), transportation and resource access, environmental regulation, shifts in demand and resource supply location, and national development policies.

The excellent presentations and discussion comments included in these proceedings concentrate on systems concepts approaches to overcome problems and difficulties and adaptation of model techniques to specific client uses, rather than detailed model or pclicy simulation results. They represent major advances and broadening of the technical literature on forest sector modeling. Attendees also felt that significant improvement in international understanding among those developing forest sector models and modeling procedures resulted from this conference.

This volume was edited by Risto Seppälä, Anne Morgan and Clark Row. Riston Seppälä, Leader of the Forest Sector Project until August 1982, has now returned to the Finnish Forest Research Institute in Helsinki. Anne Morgan was Network Coordinator of the Project at IIASA until December 1982. Clark Row of the USDA Forest Service was Chairman of the Organizing Committee for the North American Conference on Forest Sector Models.

Clark Row
USDA Forest Service

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PART I

INTRODUCTION

THE FOREST SECTOR PROJECT OF THE INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS

Risto Seppälä[1]

POINT OF DEPARTURE

The forest sector (comprising forestry and the forest industry) is facing major structural changes. This is primarily due to changing patterns of production, consumption, and trade of forest products.

On the production side, development of processing technology has made the industrial use of wood possible in many new areas where wood previously had no commercial value. At the same time, wood growing has reached its economic and institutional limits in some old forest areas. As a consequence, a major shift in the global pattern of the supply of wood raw material is taking place.

Over the long term, the global consumption pattern of forest products is changing. For traditional products, some countries are reaching a saturation level whilst in others a considerable increase in demand is anticipated. At the same time, technological innovations will change the overall demand for different products. On the one hand new ways of using wood raw material, e.g., for chemical products, may increase the demand for wood. On the other hand, advances in other areas, such as the diffusion of electronic information technologies and packaging substitutes, may decrease the demand for forest products.

All these issues pose problems that require a global analysis. As for supply of and demand for forest products, trade flows form the most important link between nations. International organizations such as the FAO, as well as private consulting companies, are continuously making scenarios and forecasts on the production, consumption, and trade of forest products. These studies are a valuable source of information, but they are usually descriptive, not analytic by nature, and the forecasts often lack consistency. In earlier studies, mechanisms and structural changes have received limited attention. This has been a major impetus for IIASA to undertake the global analysis of the forest sector.

Although the problems perceived are often the results of global development and international interactions, the consequences are most apparent at national levels. Also, the solutions to these problems are nearly always local and not global. Therefore, the IIASA study will concentrate also on national and regional analysis of the forest sector. Hence, the Forest Sector Project includes two interacting tasks:

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1)Leader of the Forest Sector Project of the International Institute for Applied Systems Analysis.

- National Forest Sector Analysis
- Analysis of World Trade in Forest Products

TASK A: NATIONAL FOREST SECTOR ANALYSIS

A preliminary analysis shows that issues and problems of the forest sector vary from one country to another. IIASA cannot have expertise on the varying issues and problems of various nations. Also, the solutions to these problems are local and may differ from country to country. The Institute cannot, therefore, assume responsibility for carrying out forest sector analysis and its implementation for individual countries. This must be done by national research teams. IIASA's role is to promote national efforts and serve as a center for information exchange.

National forest sector analysis will be carried out by implementing national forest sector models. The first step in IIASA's promotion activities is to construct a prototype model that will serve as a framework for the national models. Because of the differences in the physical and institutional conditions, as well as the problems, the prototype system must be very flexible. This means that it will be a collection of submodels or modules. For each individual national forest sector model a specific set of modules applicable to the conditions of that country can be selected and linked together.

In some cases, a national model that is based only on picking out relevant parts of IIASA's prototype will not be adequate for analyzing problems within these nations. IIASA's prototype will serve mainly as a starting point, especially for those national research teams who lack earlier experience in forest sector modeling. The final national models can be much more comprehensive than any IIASA prototype.

The modules of the prototype will describe, for example, timber growth, timber harvesting, forest ownership pattern, land conversion, erosion, firewood use, wood processing, demand for wood products and government policies. In some cases, there must be different prototype modules for different conditions, e.g., separate modules for industrialized nations and developing countries.

A more detailed description of the IIASA prototype model can be found in working papers prepared by IIASA's research team. The whole series of these papers will be a basis for a Handbook for Forest Sector Modeling.

TASK B: ANALYSIS OF WORLD TRADE IN FOREST PRODUCTS

The primary objective of this task is to study the global structural change of demand, supply, and trade in forest products. The secondary objective is to provide a global framework within which the policy issues and plans of individual countries can be explored.

In the short term, significant structural changes in the demand, supply, and trade of forest products do not usually occur. The IIASA analysis will therefore focus on long-term policy issues up to a 20–30 year horizon. The main method of analysis is to construct a computer-based model of the world's forest sector. It will consist of a set of national and regional models that have been linked together.

Linking detailed national models to a global system inevitably produces a very large model. Large models tend, however, to fail. In addition, some national models needed for the linkage have been or will be developed independently of IIASA's project. Independent models can easily become incompatible. In order to ensure compatability and manageability of the global model, we have to assume that the national and regional models, which will be linked together, are based on a common frame.

The global forest sector model will not be primarily a forecasting model, but rather a policy analysis model, where the structural and functional mechanisms of the system are the basic elements. When forecasts are made, they are conditional, elucidating the different consequences of policy alternatives.

ORGANIZATION

A relatively small full-time staff, whose role will be coordination and consultation, is being established at IIASA. However, IIASA's staff will also be in charge of building the prototype forest sector model and the global linkage system.

An extensive program of visiting scientists and experts has been established. In most cases these visitors are seconded from their home institutions and will stay at IIASA for periods ranging from a couple of weeks to a couple of months.

A substantial part of the work, especially in Task A, will be done in participating countries. Therefore, a network of collaborating national research teams is being established. National teams will be encouraged to form advisory groups to create the necessary connection with the users of results. Advisory groups will help ensure that work is realistically directed, and that results will be made known and applied.

Many international organizations are necessary collaborators in the Project, especially for the analysis of world trade. Working relations have been established with four organizations having activities similar to those of the IIASA Project: FAO's Forestry Department, FAO/ECE's Agriculture and Timber Division, UNIDO's Sectoral Studies Branch, and IUFRO (the International Union of Forestry Research Organizations).

Meetings and seminars sponsored by IIASA, held both at IIASA and other countries, are vital to the project. Information about future meetings and recent developments within the Project can be obtained from *MODULES*, The Forest Sector Project Newsletter, published on a quarterly basis.

IMPLEMENTATION AND CONTINUITY

Even the most elegant policy models and the brightest results of policy analysis are of little value if they are not used in the decision making process. For this purpose, the advisory groups representing the users are being established in each collaborating country as well as at IIASA. The aim is to involve the users deeply in the process from the very beginning.

Every effort will be made to guarantee the continuity of the work after its completion at IIASA. Two project groups have been established within IUFRO to provide a home for forest sector modelers and world trade analysts. IUFRO cannot, however, provide either financial support or premises, but its organizational setting guarantees that the extensive network of researchers that is being created for the Project can survive.

If the implementation of the Project succeeds as planned, the global trade model will be transferred to and used in different countries and international organizations. Negotiations will take place to find an institution that is ready to maintain and update the model after completion of work at IIASA.

BUDGET AND FUNDING

After a year's pilot study, IIASA's Forest Sector Project commenced in September, 1981. According to the present plans, it will be completed by mid 1985.

Altogether nearly 30 scientific person years will be needed to carry out the project during the four year period. Two-thirds of this input comes from permanent IIASA staff (core) and one-third in the form of secondments in which the sending institutions will pay direct salaries.

The total IIASA budget for the project for the period of September 1981 to June 1985 is 20 million Austrian Schillings. If salaries of seconded persons are taken into account, the overall budget is 25 million Schillings (= 1.5 million US Dollars). This figure does not include the work done by collaborating teams in participating countries.

The funds coming from IIASA's internal budget cover two-thirds of the 20 million Schillings budget. The rest, i.e., more than 6 million Schillings, is expected to come as grants from external sources.

PART II

APPROACHES TO DEVELOPING FOREST SECTOR MODELS

RESEARCH ON TAMM AND OTHER ELEMENTS OF THE U.S. TIMBER ASSESSMENT SYSTEM

Richard W. Haynes and Darius M. Adams[1]

Abstract.-- This paper describes current research efforts to revise and improve the Timber Assessment Market Model (TAMM). Major changes are planned in the demand and supply structures for solid wood products (including the addition of market models for reconstituted wood panel products), in the pulp, paper, and board model, in the modelling of international trade flows for all products, in the projection of technological and factor productivity shifts, in the models of private timber supply behavior, and in the timber inventory projection model.

Additional keywords: econometric models, long-range market projection, policy analysis.

INTRODUCTION

During the past decade, forestry sector models in the U.S. have evolved from simple procedures that projected the "gap" between aggregate timber consumption and production at prespecified price levels to complex systems capable of simulating consumption, production, and price behavior for an array of products in spatially disaggregated markets at both the final product and stumpage levels. At the same time, application of these models has expanded appreciably in both the public and private sectors. With earlier models, use was restricted largely to the evaluation of market trends in the absence of policy action. The models could give an indication of the nature of future market developments but were of little value in assessing the pros and cons of alternative policy responses. Current models, in contrast, provide both a greater capability for policy analysis as well as a broader array of information on potential policy impacts. As a consequence, they are gaining increased acceptance as tools in the policy development and evaluation process. This paper discusses ongoing research efforts to improve the forest sector model used by the U.S. Forest Service for its long term planning and policy evaluations. The model system is the Timber Assessment Market Model--TAMM (Adams and Haynes, 1980) developed jointly at the Pacific Northwest Forest and Range Experiment Station and the Department of Forest Management at Oregon State University.

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1) The authors are, respectively, principal economist, U.S. Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, and associate professor, Department of Forest Management, Oregon State University, Corvallis, Oregon.

AN OVERVIEW OF TAMM

TAMM was developed both for making projections of activity in forest products markets and for evaluating a broad range of alternative policies over a 50 year projection period. The principal concern in projections was with the identification of broad trends in market activity rather than short-term cycles. Thus, for the product markets where it was appropriate, a simple supply-demand framework was employed, utilizing annual time series data for estimation purposes. Spatial interaction in product markets was given explicit consideration.

An overview of the TAMM system is given in Figure 1. For lumber and plywood, demand equations were developed for each of seven demand regions; supply equations were developed for seven supply regions including Canada. Spatial equilibrium in these markets was determined by a process that explicitly considered transportation costs. Consumption of paper and board products was projected using income-consumption relations for the entire U.S. After adjustments for imports, projections of domestic pulp production were developed by supply region. Projected output of fuelwood, miscellaneous products, and log exports in each supply region was based on estimates of future consumption and trade in these products developed outside of the model. Total demand for stumpage in each supply region was derived from conversion of product supply volumes (for lumber, plywood, pulp, etc.) to roundwood equivalents. Supplies of stumpage consist of public harvests set by policies of federal and state agencies, and private harvests which were responsive to both stumpage price and available inventory volumes. Equilibrium in each regional stumpage market was determined by simple supply-demand equation. Timber inventory volumes by ownership and region were projected using the TRAS model (Larson and Goforth, 1974).

Boundaries of supply and demand regions in the model do not, in general, coincide. Demand regions (Figure 2a) were defined based on major geographical concentrations of forest products consumption. Lumber and plywood demand equations were estimated for these regions. Supply regions (Figure 2b) encompass principal concentrations of forest products output. Lumber and plywood supply equations, pulp production estimates, and all stumpage market activities were developed for each of the supply regions.

In TAMM spatial equilibrium in the lumber and plywood markets is found in each year of the projection period. It should be noted that these solutions do not represent intertemporal production or consumption strategies which are in some sense optimal. The production, consumption, and price time paths are only estimates of the outcomes of contemporaneous interactions in freely competitive markets.

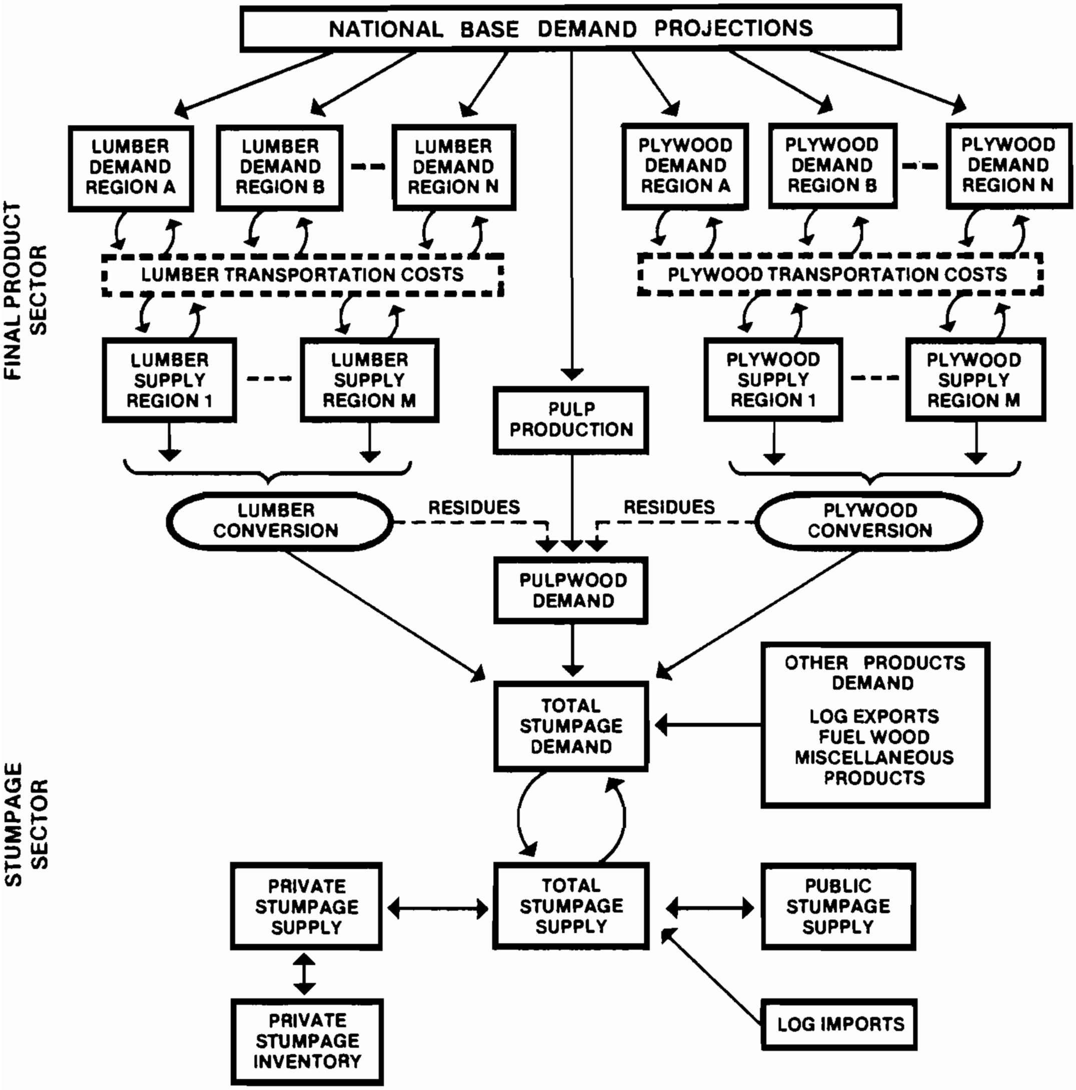
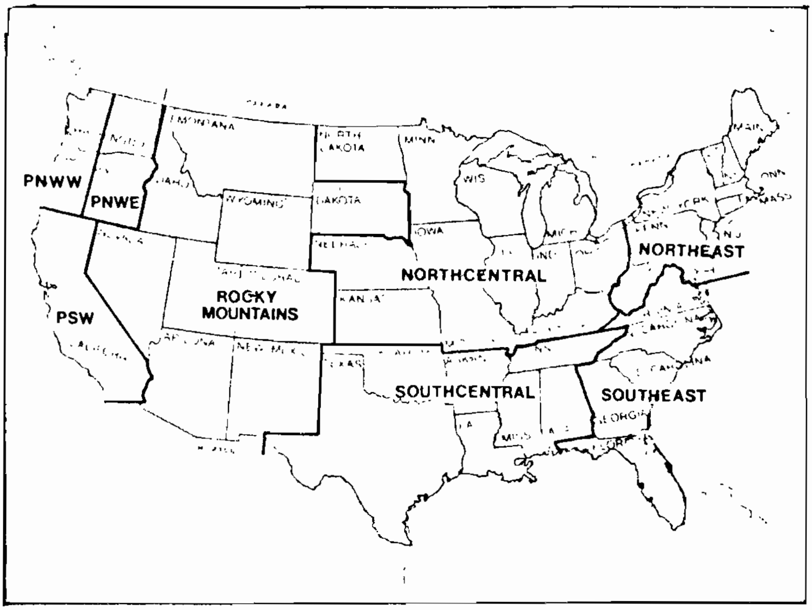
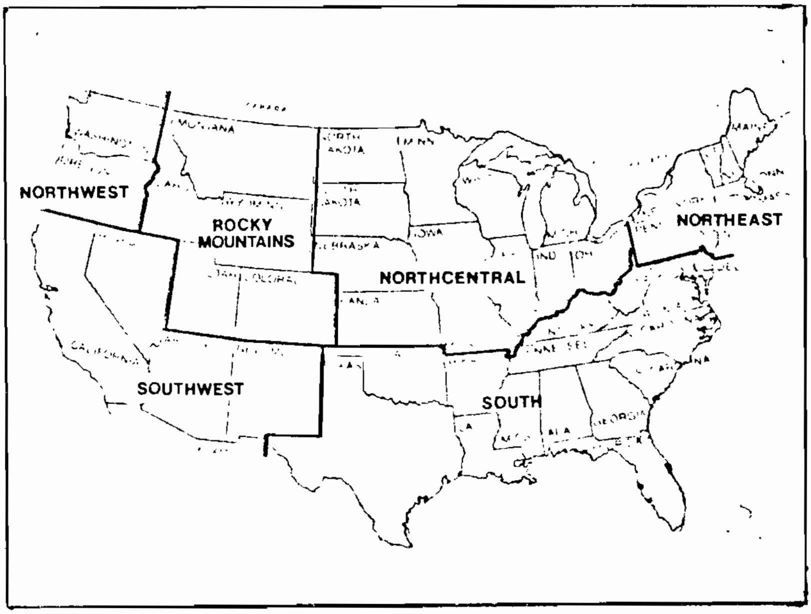


Figure 1 Major interactions in the timber assessment market model (TAMM). Curved arrows indicate locations of market price-quantity determination. Single or two headed straight arrows indicate unidirectional or multidirectional causation. Detail in stumpage sector shown for only one region.



(a)



(b)

Figure 2 Demand (a) and supply (b) regions used in TAMM.

Research on TAMM has provided some useful insights into several areas of general concern in market modelling and long-range forest policy analysis.

(1) Interregional and interowner diversity and interaction in both product and stumpage markets are essential characteristics influencing market behavior. From the modelling standpoint, aggregation entails significant risk of misrepresenting market response over time. For policy analysis interregional and interowner substitution have a profound influence on the effectiveness of many forest policies. Policy simulations with TAMM clearly suggest that policy actions can not be formulated for a single region or ownership without considering the response of other regions and ownerships.

(2) The dynamics of private timber supply behavior in the long-term is one of the most poorly understood elements of forest products markets, yet potentially one of the most critical. Simulations of private timber management investment behavior using TAMM suggest that private lands may be capable of timber output sufficient to produce stable or even declining forest products prices by the next century. Timber policy debate in the U.S. in the 20th century has focused almost exclusively on means of augmenting supply in the face of rapidly rising demand. Such analysis as has been conducted has generally assumed fixed or only modestly increased levels of management intensity on private lands. The possibility of widespread adoption of intensive management suggests the need to at least consider a radically different scenario, one in which the need is to find markets for an abundant supply.

(3) Work with TAMM has highlighted the importance of a thoroughgoing analysis of costs in efforts to model and project mill level supply of forest products. Production costs are the basis for producer price formation. Decomposing costs into major components of the production process, e.g., stumpage, logging, hauling, and manufacturing, and these in turn into basic elements, such as labor and energy, provides significant insights into the supply behavior of firms, the role of changing factor productivity, and the bases for shifting comparative advantage among competing regions.

TAMM (including TRAS) provides a comprehensive and consistent means to evaluate the impacts of various policies. Changes in the stumpage sector, which is the primary focus of most Forest Service policies, can be translated into impacts in the product market, enabling better identification of the incidence of policy costs and benefits. Regional interactions and redistribution of costs and benefits induced by policy shifts can be quantified. Reactions of private timber producers to public policy shifts can also be estimated together with the long-term impacts on the private timber resource. Because the current system is computerized and, in effect, centralized in a single location (given that all of the preliminary input to TAMM and TRAS has been obtained) policy analyses can be conducted in a timely fashion and at reasonable cost. Policy questions can be analyzed under the same assumptions and conditions about the economic and resource management environment. Thus, if the indicated impacts of two policies differ, the analyst can be certain that the differences arise from the policies themselves and not from different assumptions or methods employed in the analytical process.

CURRENT EFFORTS TO REVISE TAMM

Widespread review of both the structure of TAMM and the projections made for the 1980 RPA Timber Assessment has suggested five broad areas needing improvement:

1) the analyses of demand and supply for lumber, panel products,and pulp and paper;
2) the analsis of international trade for all products;
3) the projections of changes in factor productivities;
4) the analysis of private timber supply behavior; and
5) the timber inventory projection system (TRAS).

The remainder of this paper deals with our efforts to address these problems. The overall goal of this work is to develop an operational system for the conduct of timber resource and market assessments capable of projecting product and stumpage market activity and forest resource conditions on a regionally disaggregated basis in the U.S. under alternative assumptions on public forest policies, private management activities, and alternative scenarios of economic conditions.

A diagram of the revised TAMM system is shown in Figure 3. The product sector will be expanded by the inclusion of modules for the pulp, paper, and board and reconstituted wood panel products markets. Determination of production, consumption, and prices (mill and delivered) by grade and region will be endogenous to these modules. Incorporation of an endogenous pulp sector will also allow more comprehensive treatment of residue markets, including price determination. Stumpage market activity will be divided into sawtimber and pulpwood elements and a pulpwood pricing mechanism will be added. As in the current version of TAMM, only private timber harvest and inventory (by region and owner group) are determined within the system. In the revised TAMM, however, private harvest will be split by sawtimber and pulpwood groups and (in selected regions) a new timber inventory projection system will be used. This new system will: (1) employ an age class representation of the inventory, (2) account for inventory by site, stocking density level, management intensity class, and age, and (3) include explicit mechanisms for shifting areas among the several management intensity classes over time.

The five broad problem areas identified in the current version of TAMM have been broken down into a number of research tasks. In specifying the tasks, it is assumed that the general form of TAMM employed in the 1980 RPA Timber Assessment (USDA Forest Service, 1980) will be retained. In this way work can procede in a modular fashion. As each task is completed it can be added to the larger model, gradually building up the full proposed system capability.

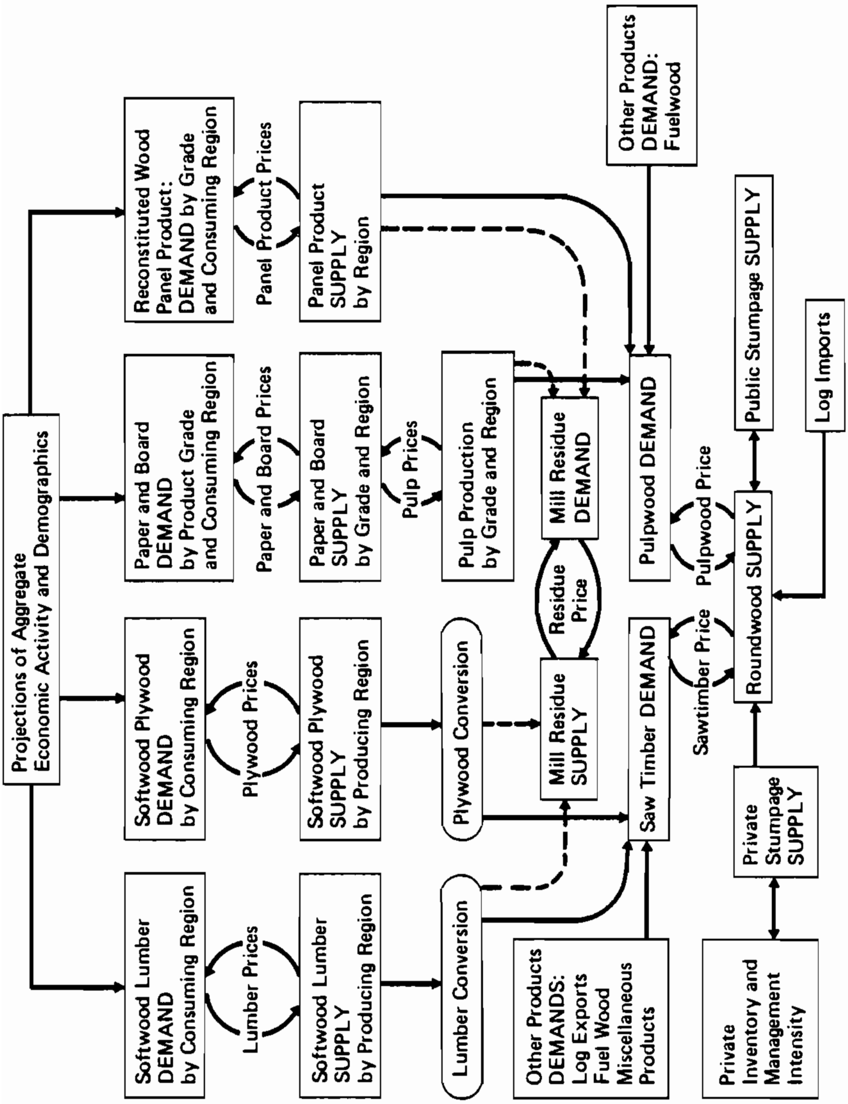


Figure 3 Major interactions in the revised TAMM system.

Task A. Revision of Product Demand and Supply Structure

Demand projections in the last Assessment were developed by a qualitative process that did not explicity consider product prices, prices of substitutes, or the dynamics of demand adjustment to shifts in relative prices. As a consequence, it was not possible to examine alternative assumptions on trends in substitute prices, and consumption behavior varied only with price in the current period regardless of prior price levels or trends. One objective of this task is to develop for lumber, plywood and reconstituted wood panel products a set of economically consistent regional demand relations built up from end-use factor equations that include relative product and substitute prices. These relationships would also include dynamic adjustments for price impacts over time (multi-period elasticities).

The current solid wood products supply structure includes both conventional price-quantity relationships and relations describing rates of capacity change. The objectives of this task include examining alternative supply function specifications, alternative approaches to modeling capacity change, and inclusion of supply models for reconstituted wood panel products. A part of this effort is a revision of the method used to project changes in factor productivity, e.g., wood and labor use per unit of product output. Figure 4 shows details of interactions in the solid wood products markets and how the various elements of demand and supply research fit together. For these products, the basic framework remains essentially unchanged from the current TAMM structure.

We also plan to include a more comprehensive model of the North American pulp and paper industry. In the 1980 Assessment, pulp and paper consumption was projected as a function solely of various measures of aggregate economic activity. Pulp production was computed by converting paper and board consumption (adjusted for trade and recycling) to pulp equivalents. Pulp production was allocated across regions on a judgemental basis considering relative wage rates, levels of softwood and hardwood growing stock, and mill residue availability. Wood requirements necessary to meet the given regional pulp output were determined by extrapolating historical regional trends for the mix of pulping types, roundwood and residues, and hardwoods and softwoods. Technical improvements (in wood losses in pulpwood handling and in gross pulp yields) were projected on a judgemental basis and applied uniformly over time.

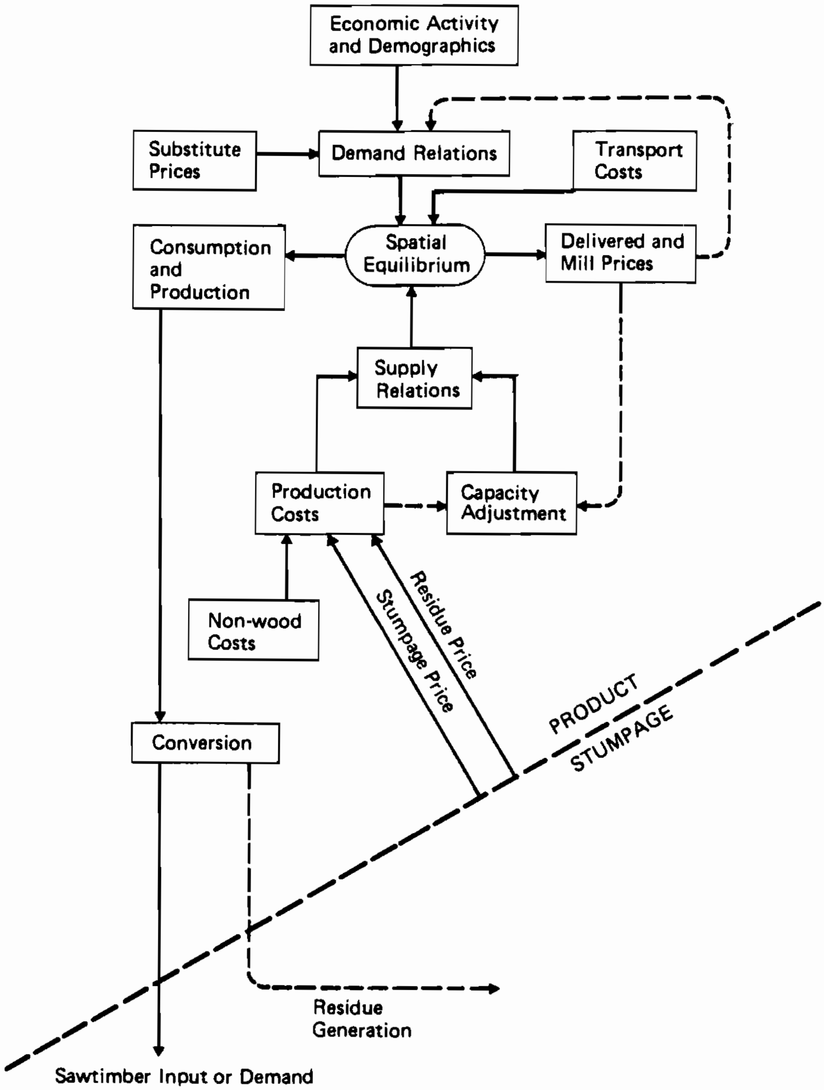


Figure 4 Market interactions for lumber and plywood.

Four lines of research on pulp and paper markets have been initiated:

(1) development of demand models for paper and board by broad product class;
(2) development of a model of pulp and paper production and capacity by region in North America;
(3) development of a process for projecting trade flows of pulp and paper products between countries in North America and between North America and other world consuming and producing regions;
(4) development of a model of pulpwood stumpage and residue markets by region in the U.S.

Research for the first three objectives is described by Professor Joseph Buongiorno in another paper in this symposium. The goal of this work is to provide a market structure for pulp and paper products with consumption, production, and prices endogenous. A key concern in model development is incorporation of processes to explain capacity expansion and shifts between regions. In the case of the fouth objective we are expanding our treatment of the stumpage sector to include pulpwood and residue prices as well as sawtimber prices.

Task B. International Trade

International trade, with the exception of Canadian lumber exports to the U.S., are currently projected on a judgmental basis. This approach has been criticized not for the level of the projections but for their insensitivity to changes in domestic U.S. supply-demand conditions. Trade flows of pulp and paper products will be modeled in the pulp products module discussed above. For solid wood products, our plans are to add Japan as an explicit demand region for softwood logs and lumber to complete the endogenous description of the U.S.-Japan-Canada trade triangle. We also expect to add price responsive trade relationships (empirical excess demand relationships) for softwood lumber and plywood shipments to Europe. These relationships will be used to estimate the effect of timber supply changes in the U.S. and other major softwood producers on our competitive trade position. Dr. David Darr will describe the proposed revisions in another paper in this symposium.

Task C. Revision of Techniques for Projecting Technology and Productivity Changes

Projections of changes in product recovery factors (in the case of lumber and plywood) and gross pulp yields in the current version of TAMM were made on a judgemental basis by technical experts. There is no direct coordination with, or consideration of, other elements of the assessment projection process. Projections of other input/output (or factor productivity) trends, such as labor use per unit of output, are made independently of recovery and yield projections and it is not clear that the two sets of projections are consistent. In both cases the time paths of projected changes are arbitrary.

Studies in other industries suggest that rates of technical change and productivity improvement are closely linked to industry profitability. Research is now underway to establish productivity-profitability linkages for wood, labor, and other major input classes for softwood lumber, plywood, reconstituted wood panel products, and pulp and paper. Initial efforts are directed at assessing historical productivity-profitability relationships in the forest products industry at both the national and regional levels. This analysis will employ the cost and profitability data developed in Task A above as well as productivity data for labor. In the second phase of research, models will be developed to allow the segregation of factor productivity shifts due to technical change and those due to changes in relative factor costs (under the same technology). This analysis should provide a means for developing consistent shifts in labor, wood, and other input productivities. Finally, econometric or approximate links between productivity and profitability will be estimated.

Task D. Revision of Models of Private Stumpage Supply

The short-term stumpage supply relations in TAMM are weak both in terms of theoretical justification and historical explanatory power. The mechanisms used to explain long-term private investment in forest management suffer from similar problems. We plan research to investigate the modification of current supply processes to better recognize the temporal interdependence of private harvesting and management decisions and consideration of other than timber benefits in private harvesting decisions.

Task E. Revision of the Timber Inventory Projection System

In the current version of TAMM, inventory changes associated with projected harvests and assumed levels of timber management activity were made using the TRAS model. In simulating management intensity changes, the use of TRAS was cumbersome because it was originally developed to operate under the assumption that radial growth, mortality, and ingrowth relations remain stable over time. TRAS operates with highly aggregated inventories, viz., a single inventory for each region/owner group. This is advantageous in that it reduces the time and cost of inventory projections, but it also entails a considerable loss in the biological realism of the growth projection process. The objective of this task is to develop an inventory projection system that retains the positive aspects of TRAS (input generated from existing data, wide flexibility in degree of geographical aggregation, low projection costs and time requirements) while overcoming its lack of biological realism and difficulties in simulating the effects of intensive management.

Research is underway to develop an alternative inventory projection system for use in regions and forest types which are predominantly even-aged in structure. This new system will describe the inventory by means of age classes rather than diameter classes as was the case in TRAS. The inventory will also be carried in a much less aggregated form than in TRAS, each acre in a given region/owner group being categorized by species group, site class, stocking density class, management intensity class, and age group. Volume per acre will be projected by yield tables specific to each of the above categories. With management intensity as an explicit descriptor of stand condition, simulation of changes in management intensity over time is readily accomplished by shifting acres among the various management intensity classes. Professor Phillip Tedder will describe the details of this research in another paper in this symposium.

Other Research Efforts

There are a number of other research projects now underway that will expand the capabilities of TAMM.

(1) Revision of the hardwood market model starting with a detailed examination of hardwood stumpage price behavior and formation, the hardwood/softwood mix in pulp production, and the development of a model of the hardwood pulpwood market. The second step is to incorporate the hardwood market model into TAMM. This would allow for direct subsitution between hardwood and softwood products in various end uses as well as raw material for pulp manufacture
(2) The development of a model of delivered wood costs to lumber and pulp producing plants in Canada based in part on the locational and quality characterisitcs of the timber harvested. The model will be used to project production cost trends in Canada and to estimate changes in harvest flows resulting from alternative harvest policies..
(3) The incorporation of Alaska in TAMM as a competitive supply region for the Japanese market. In the 1980 Timber Assessment, Alaska was treated as an independent projection component that did not interact with either U.S. or Canadian markets. In the revised TAMM, Alaska will interact with U.S. and Canadian west coast markets as an alternative source of supply for Japanese markets.
(4) The development of an accounting system for estimating social, economic, and environmental impacts associated with changes in harvest flows. This system will be linked to TAMM such that, ideally, many of these measures (i.e., various economic surpluses, employment, etc.) could be computed directly in TAMM rather than in ex post analyses.

Linkage Problems

The model revisions described above will improve the analytical capabilities of the TAMM system, but they will also increase the complexity of the model and render system solutions more difficult. For example, the revised timber inventory projection system (called TRIM) represents aggregate stands using age classes, where the class interval is ten years. The inventory is updated each decade rather than each year, as in TRAS. This raises the problem of linking the stumpage market modules in TAMM, that operate on an annual cycle and require annual inventory levels as input, with an inventory projection model that operates on a decade cycle. We propose to affect this linkage by adding a simple growth/drain model to compute annual inventories within the decade cycles. Each decade TRIM would be used to estimate net growth for each inventory group and a revised inventory for the end of the decade. This procedure is shown in Figure 5. Unless the growth employed in the growth/drain model is the same as the actual net periodic annual increment over the decade (which can not be known in advance), the inventory level produced by the growth/drain model in the tenth and final year of each decade cycle will differ from that projected by TRIM when the full inventory is updated. This difference will be resolved by an iterative procedure where TAMM will be rerun for the decade until the estimated ending inventory from the growth/drain model agrees (within some tolerance) with the updated inventory from TRIM.

Another linkage problem arises in the case of the pulp and paper model. This model employs a linear programming procedure to solve for spatial equilibrium. The technique, while relatively easy to apply, usually results in large linear programming matrices and fairly lengthy solution times. We hope to reduce the computational burden by use of the basis from the current year's solution to provide a near optimal starting point for next year's solution.

These are just two problems that complicate the solution of TAMM. In the end we must have a model of the forest products markets that can be solved rapidly and cheaply. If we complicate the model too much or make it too expensive to run (say more than $200 per run) then we have defeated our purpose of developing an operational policy tool.

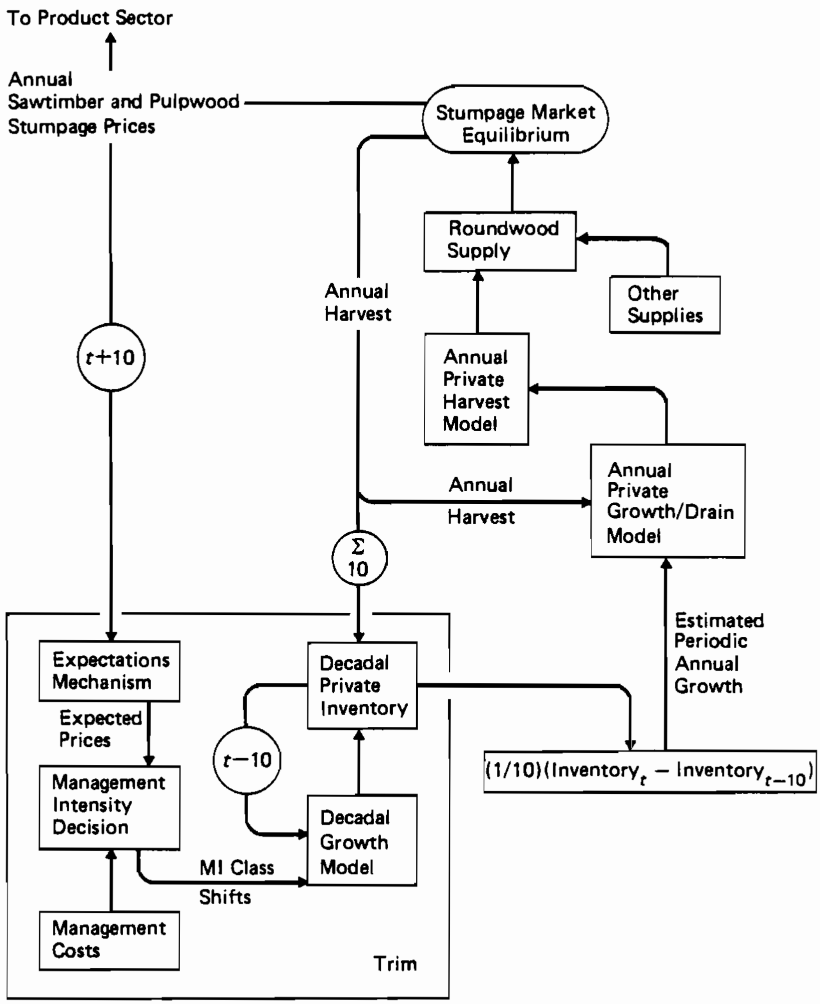


Figure 5 Interaction between TRIM and TAMM.

Research Deadlines

The proposed time sequence for completion of the several modifications in TAMM is shown in Figure 6. We are working toward two deadlines. The first is this coming summer when we will update the 1980 RPA Timber Assessment. The equilibrium projection included in the Timber Assessment was made in 1979 using data through 1976. We will revise the current version of TAMM for the update. Specific tasks include:

1) reestimating all empirical relationships with data series updated through 1980
2) adding logging residues as a source of fiber for the pulp model
3) adding pulpwood markets
4) using revised TRAS decks where available
5) updating all costs and other exogenous variables
6) developing demand projections from explicit end use relationships.

During the first six months of 1983, TAMM (now TAMM2) will be extensively revised to meet the original goal of having an operational system capable of projecting product and stumpage market activity and forest resource conditions on a regionally disaggregated basis under alternative assumptions about public harvest levels, private management activities, and alternative scenarios of economic conditions. TAMM2 will feature Canadian supply models, the revised inventory projection system, the pulp sector model, a revised system for making technological and productivity changes, and an enlarged regional structure. It will be flexible enough to simulate a wide range of policy actions.

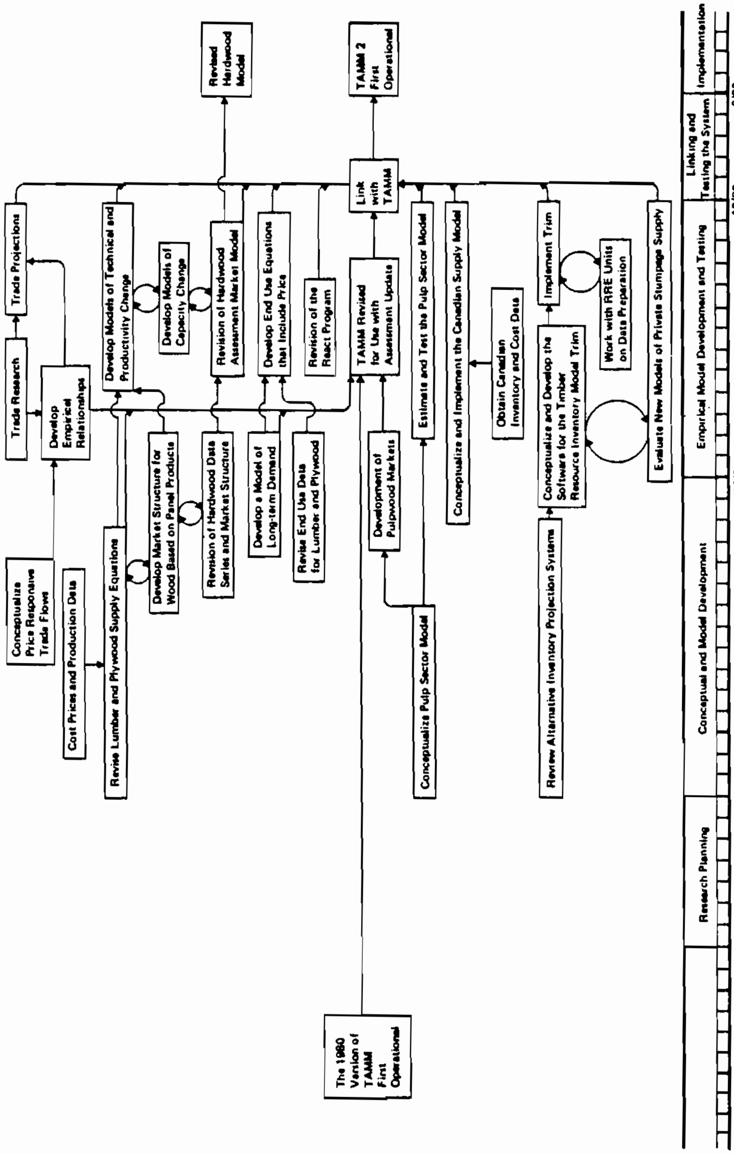


Figure 6 Time and task sequence for revising TAMM.

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RESEARCH ON TAMM AND OTHER ELEMENTS OF THE U.S. TIMBER ASSESSMENT SYSTEM--DISCUSSION

Dale Kalbfleisch[1]

The TAMM authors are to be commended for continuing research designed to improve the forecasting and simulation capabilities of their model. From the description of how TAMM has been used, it is obvious that TAMM is a tool that can and will play an increasingly important role in the U.S. Timber Outlook and RPA processes.

Although a model must be an abstraction from reality, it must, in order to be really useful for policy analysis, simulate realistically the complex interactions that would result from alternative policy actions. Although the current TAMM is considerably improved in that regard over the earlier versions, the authors correctly recognize that further improvements in structure and specification are required. The planned improvements will, if they can be accomplished, provide better results by more realistic modeling of the processes that determine key product and raw material flows and prices. Certainly making product substitution responsive to relative price is a step forward.

Utilizing the concept of investment incentive to explain pulp capacity location is a realistic way to model how decisions are made in the real world. Incorporating price as a determinant of trade flows is another step toward realism and will allow better policy analysis by helping to understand the importance of competitive behavior in world markets. This research should also aid in understanding how to link to the IIASA trade system.

The recognition that solid wood demands on the raw material resource impact price differently from fiber demands can potentially produce significant changes in the TAMM results. Incorporating profitability as a determinant of the rate of adopting technical improvements, and, therefore, timber demand, is another step toward realism.

The simulation results of the current TAMM are questionable because the system has no real link to a measure of Canada's timber inventory in an economic sense. Although undoubtedly a difficult modeling task, the proposal to characterize economic supply as a function of quality and accessibility should be a better measure of Canada's ability to compete in U.S. markets.

Probably the most important area of research, at least in the longer term outlook and policy evaluation setting, is to improve the ability to model forest management investment and, therefore, supply capability in future years, as a function of economic incentives. Timber supply is more than biological and the intensity of forestry management is a variable that must be consistent with the returns to that investment if the results are to be credible and realistic. These areas of proposed research can substantially improve TAMM's outlook and simulation capabilities. I suspect the authors

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[1]Weyerhaeuser Company, Takoma, WA.

will find it impossible to make all the changes in an econometric formulation with statistically significant parameters. Hopefully, this will not deter them from making the change, and they will substitute realistic estimates from engineering or other studies instead.

In the past, the TAMM authors have made their preliminary results easily available for inspection and critique. As they move to modeling these more complex and data-poor areas, this evaluation and critique process becomes even more important. I urge those of you with an interest in forest sector modeling to make the effort to examine preliminary results thoroughly and offer the authors all the technical assistance and industry insights you can. Only in this way can the rate of progress in forest sector modeling, which has been commendable in the past, be continued.

A POLICY ANALYSIS MODEL FOR THE FINNISH FOREST SECTOR

Jari Kuuluvainen and Risto Seppälä[1]

BACKGROUND

Because of the rapid expansion of the production capacity of the primary forest industries in Finland, the annual allowable cut was temporarily exceeded at the beginning of the 1960s. This led to increased investments in forestry to guarantee sustainable yields in the future. Concern over the optimal allocation of forestry inputs was the first step towards building a forest sector model.

It became evident, however, that it was not reasonable to concentrate on wood production in isolation from the forest industry. Therefore, a project to construct a policy analysis model for the whole forest sector (comprising both forestry and the forest industry) was initiated in 1974. The aim of the project was to develop a tool for decision makers to study and evaluate the long-term consequences of different policy options. The study was completed in 1979.

STRUCTURE OF THE MODEL

The model, called MESSU, is built up of seven submodels (modules) shown in Figure 1.

FOREST describes the growth and the total standing volume of the forests in Finland and gives the physical limits to the domestic wood raw material available for the forest industry. With this submodel it is possible, for example, to investigate the consequences of different inputs to forestry and their effects on forest industry production in the long run. Wood imports are also possible in the model and can be made endogenous.

FOREST OWNERSHIP. About 80 percent of the cutting possibilities in Finland are in private nonindustrial forests. This module describes the supply of roundwood from these forests. In addition to the allowable cut, the actual wood supply is determined in the model by forest ownership structure and income level. The present trend in the forest ownership structure, where the number of nonfarmers as forest owners increases, tends to decrease wood supply. The rise in income level has the same effect.

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1)Jari Kuuluvainen is working in the Department of Economics of the Finnish Forest Research Institute. Risto Seppälä is leader of the Forest Sector Project of the International Institute for Applied Systems Analysis.

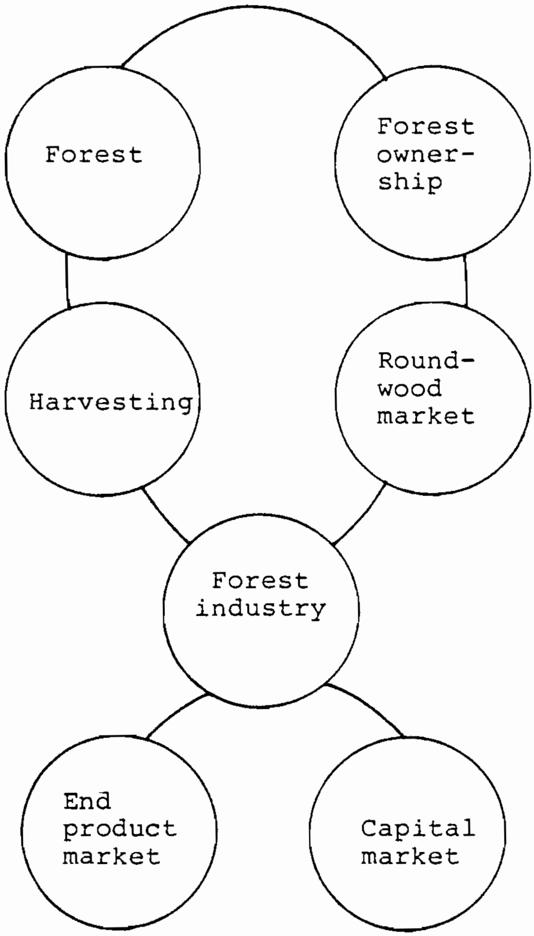


Figure 1 The general structure of the model.

The supply of and demand for roundwood meet on the ROUNDWOOD MARKET. The stumpage price and quantity exchanged are determined in this module. The relative market power of buyers and sellers is a decisive factor in prices. The demand for wood depends on the demand for the forest industrial products and on the available production capacity. The supply depends, in the long run, on the allowable cut, forest ownership structure and general income level, as determined in the forest ownership module. It is worth noting that the effect of stumpage on the supply is *in the long run* very weak. The effect of the stumpage on demand comes via capacity changes caused by changes in profitability.

The submodel for HARVESTING includes logging and transportation. In this module, a crucial problem is the relative development of capital and labor costs and their effect on the speed of mechanization of forestry operations. Also the supply of forestry labor is generated in this module and it it based on the degree of urbanization given by a population submodule.

The production capacity of the FOREST INDUSTRY is aggregated into one product and measured in equivalent tons. Only primary production of the forest industry (sawn timber, wood-based panels, pulp, paper, and board) is included. Although production is aggregated into one product, the structural changes in production can be taken into account with exogenous variables describing variable production costs and the refinement of product mix.

The forest industry submodule concentrates on the development of the production capacity. The special purpose of this part is to investigate the different strategies the forest industries have when some domestic constraints such as availability of wood, labor, or capital starts to limit expansion rate below competitors. Investments are divided into replacement and expansion investments. Possibilities to invest are dependent on profitability and the availability of loans. Because of their effect on the efficiency of the production capacity, capital investments decrease variable production costs. In principle, modern capacity means high capital costs and low variable production costs and vice versa.

CAPITAL MARKET allocates external capital to the forest industry. In principle, income finance is used first, and only when this is not enough does the forest industry enter the capital market. The amount of external finance available is regulated by two different mechanisms. The first of these is based on mutual agreement between the Central Association of the Finnish Forest Industries and the Bank of Finland. According to this existing agreement, loan finance is not available to those expansion investments that lead to cuttings exceeding the sustainable yield (allowable cut) of the forests. The other regulator is based on the financial situation of the forest industries. In principle, the industry must have sufficient liquidable funds and capital to cover the amount of external finance. The greater the need for loans in relation to this liquidable capital, the more difficult it is to obtain loans. Neither of these mechanisms is effective if loans are not needed.

The MARKET FOR FOREST PRODUCTS. The demand for and price of products are exogenous to the domestic forest industry. Changes in the market share affect the price, however, because it is assumed that the whole of production is always sold. Further, it is assumed that the competitors grow at the same rate as demand. Short-term fluctuations in the end product market are abstracted away.

GENERAL FEATURES OF THE MODEL

MESSU is a *long-range* simulation model. The time horizon stretches from 1955 to 2015. Business cycles do not appear in the model. Each annual figure represents a moving average of several years. Simulating the period from 1955 to 1980 gives a validity test to the model. Technically it is possible to expand the time horizon without limit into the future, but the usefulness of the results after the year 2000 may be arguable. On the other hand, the long-range approach in the forest sector is relevant alone because of the long rotation time of trees in Finland.

MESSU is an *interactive* model. The user of the model can, with independent decisions, influence the functioning of the model. This may take place either by using scenario techniques or by communicating directly with the model through a computer terminal.

MESSU is a typical *policy analysis* model. It does not make decisions on our behalf. In place thereof, it is a tool to be used in a policy-analysis and decision-making process. It is meant to give information about the structure and behavior of the forest sector. It does not necessarily give forecasts but produces alternatives for the future, based on different sets of assumptions.

MESSU is a *holistic* model. It considers the forest sector as a whole, which makes it possible to study the interaction between the different parts of the sector. The model produces information about the problems and bottlenecks to which research and decision making should pay special attention.

MESSU does not only consider *economic* features of the forest sector, even though they are a central part of the model. *Biological* (timber growth) and *technical* (efficiency of forest industry production and harvesting capacity) features are also included. Further, *socio-economic* issues, such as population, urbanization and labor supply dynamics, are considered.

A policy analysis model has not very much value if it is not used. This might occur if the users have no trust in the model. An important precondition for this trust is that the users are familiar with the model structure. In practice this means that the users must be connected to the model building process. This was one of the main ideas when the project was started. For this purpose, a *reference group* consisting of high level decision makers in different interest groups of the forest sector was established at the very beginning.

HISTORICAL DEVELOPMENT OF THE FINNISH FOREST SECTOR

The share of forest industry products of the value of total exports steadily increased from the end of the nineteenth century until the 1950s. During the 1950s about 90 percent of the total export value in Finland came from forest industry products. Since then their relative share has decreased, due to the rapid expansion of other sectors, and it is now about 40 percent of the total value of exports.

The industrial use of wood raw material started in Finland during the 1860s, when the first steam sawmills were built. The industrial use of wood has been steadily increasing ever since, excluding the periods of the two Word Wars and economic depressions. Between the two World Wars the forest industries became the largest user of wood. At the same time the role of forestry changed and its main purpose became the raw material supplier to the continuously growing forest industries.

The total drain grew further after World War II and by the 1950s the annual allowable cut was moderately exceeded. At the beginning of the 1960s the sustainable yield principle seemed to be in permanent danger. However, the decrease in the nonindustrial use of wood, the switch from net export of roundwood to net import, and the increase in the utilization of industrial wastewood, along with weakened supply of non-industrial private forest owners, have been the main reasons for the fact that since the mid-60s total drain has been permanently smaller than the allowable cut.

A historical review shows that the 1960s appear to be a turning point in the development of the forest sector in Finland. The total drain (cuttings) started to decrease, the stumpage prices in real terms started to make a continuous rise, the market share of the Finnish forest industries in the world market started to decrease, and profitability turned into a downward trend. This development was partly accelerated by the depression in the mid-70s. At that time, for example, the total loans of the Finnish forest industries exceeded the yearly turnover. The competitiveness was in serious danger because of the low profitability and poor financial situation. It must be stressed that, even though the depression in the middle of the 1970s made things worse, it was not the reason for the unfavorable development. The roots of the problems date from the 1960s.

BASIS FOR THE FUTURE

The problems of the primary production of the forest industries in Finland have two main sources: domestic raw material constraint, and low profitability of the industry connected to a weak financial situation. The availability of wood raw material is not only constrained by physical availability (sustainable yield or allowable cut), but also by the decreasing supply from non-industrial forests and the scarcity of forestry labor. The human and institutional constraints are probably changeable with effort, but the physical raw material constraint remains.

The profitability and financial situation of the primary forest industries is in the long run closely connected to the availability of wood. Scarcity of wood tends to bid up the wood prices, which decreases industries' profitability. Scarcity of raw material can also cause the domestic forest industries to grow more slowly than competitors. Slow growth easily means relatively older production capacity than that of faster growing competitors. This can be prevented only with increased costs to replacement investments. In any case, total costs of production tend to rise, thereby decreasing profitability. Decreasing profitability may in due course become an even stronger limit to investments than the availability of the raw material. All this can cause the underutilization of forest resources, which again decreases the cutting possibilities in the future. In an industry where production technology is international and tightly connected to the age structure of the production capacity (putty-clay technology), dropping from the markets' growth path may be fatal.

POLICY OPTIONS

MESSU is a computer model and, therefore, different policy options based on different assumptions can be produced easily. In the course of the study, the model was run thousands of times. In the following, however, only two scenarios will be presented.

1. Passive Alternative

The first scenario, which is called the basic run, gives the future based totally on the structures and relationships of the past as determined in the model. This means that we do not try actively to affect future development. The scenario in Figures 2-5 is certainly not going to materialize, because the structures of the past will not remain. Besides, unfavorable development causes reactions in order to change directions.

According to Figure 2, the production capacity experiences a period of rapid expansion from 1955 to the beginning of the 1980s. This is followed by a period of stagnation, and new growth of capacity starts after 1985. This growth stagnates again, however, after 2000. Stagnation at the beginning of the 1980s is caused by the scarcity of wood raw material due to forest owner's unwillingness to sell with current prices, labor restrictions on cuttings and forest industries low profitability coupled with the unwillingness to invest.

Figure 3 shows how the unwillingness of the private non-industrial forest owners to sell the wood has pressed the potential supply under the allowable cut level since the end of the 1960s. This restriction constrains cuttings until the beginning of the 1980s, after which the constraint is the forestry labor supply. After the 1980s labor supply for harvesting is no longer a restriction, but it follows the decrease in fellings due to the decrease in the industrial production capacity.

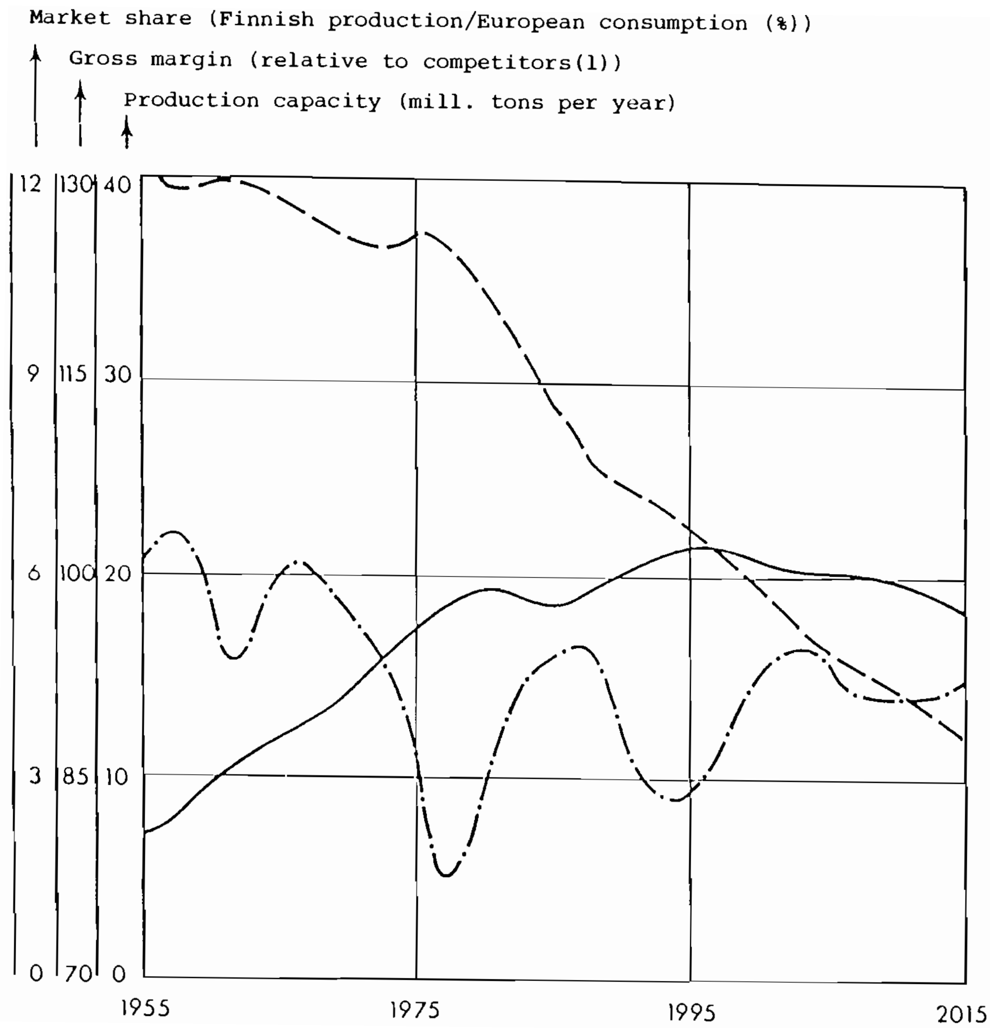


Figure 2

Production capacity includes sawmilling industry, panel industry, pulp, paper and cardboard industries, measured in equivalent tons per year.

Gross margin is obtained by subtracting variable production costs from total sales income. In the figure, gross margin is given relative to competitors whose gross margin is 100.

Market share is the share of the total Finnish production of the total consumption of forest industrial products in Europe.

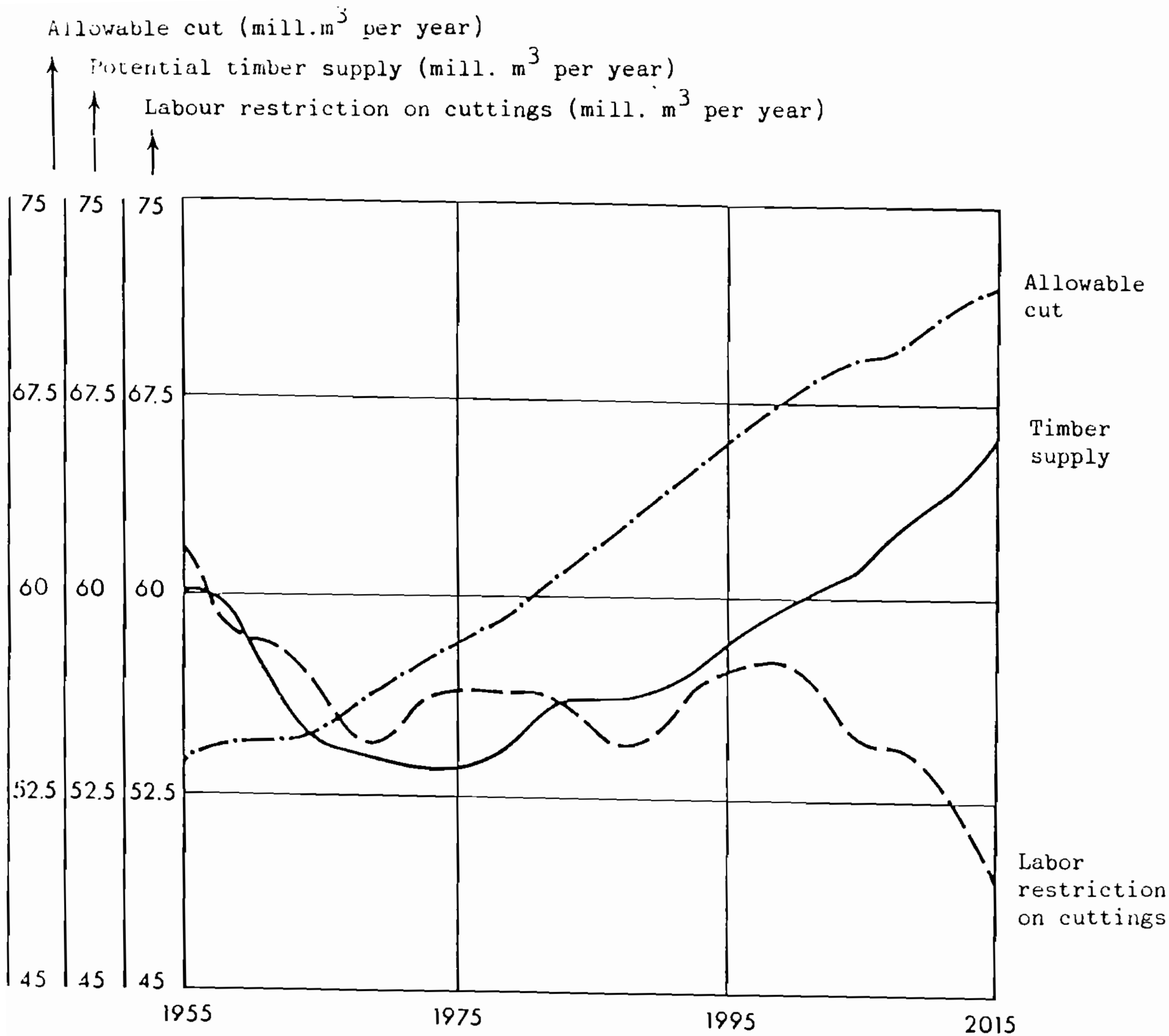


Figure 3
Allowable cut is the growth of the forest adjusted for the age structure; also silvicultural activities affecting the cutting possibilities are taken into account.
Potential timber supply gives the total autonomous supply of timber independent of the stumpage level. It is assumed that government and the forest industries supply the amount dictated by allowable cut. The supply from private nonindustrial forests depends on the forest ownership structure and on the income level. Potential supply includes the amount supplied to industrial use and aslo fuelwood, other nonindustrial use of wood and waste wood.
Labor restriction on cuttings gives the cutting possibilities with the labor available in forestry.

Figures 4 and 5 show the economic consequences of the above described development. Stumpage prices in real terms rise rapidly until 1980, harvesting costs rise slightly at the beginning of the 1980s and the variable production costs are in a steady, although slow, rise during nearly the entire simulation period. Rising production costs and heavy replacement and expansion investments increase the amount of loans rapidly. At the beginning of the 1970s the loans in relation to annual sales income start to increase at the same time as income finance decreases. This makes the expansion investments and even a part of the replacement investments impossible at the end of the century, leading to a capacity decrease.

The above run suggested a somewhat depressing picture for the future of the Finnish forest sector. The run was based on some kind of a laissez faire mentality, and the unfavorable development did not cause actions to stop it. Therefore, this scenario can be called a *passive alternative*.

2. Active Alternative

In this second run we have made a set of assumptions about actions that should be feasible in reality. In the previous run, both roundwood and labor supply restricted the industrial capacity expansion. We now assume that these restrictions can be dismissed by the mid-1980s.

In the passive alternative, the expansion investments of the forest industry in the early 1980s were also seriously restricted by the weak financial situation. We assume now that world market price is given as before, but a better profitability can be obtained by giving the forest industries a stronger position in the roundwood market than in the previous run. Greater supply already means less pressure for stumpage to rise.

In this run the supply of roundwood and forestry labor do not restrict cuttings. However, the limit imposed by sustainable yield remains. We assume here that investments to silvicultural activities are raised to a level effecting an increase in annual allowable cut by 0.5 mill m^3 per year. Further, we assume that raw material is used more effectively, so that from one cubic meter of wood we get about 25 percent more products at the end of this century than in the previous scenario. The import of roundwood is endogenized and the forest industry is able to import a maximum of 20 percent of its total use of wood.

With the above rather extreme assumptions we get the results seen in Figures 6 and 7. The financial situation of the forest industries has now considerably improved. Because allowable cut can be fully utilized, a new capacity expansion begins around 1985. However, the short stagnation period at the beginning of the 1980s remains. This is due to the fact that the financial situation is already weak at the end of the 1970s and the past was not changed in our assumptions. Therefore, the investments at the end of the 1970s and the early 1980s are mainly replacement investments.

We have extended the time horizon in this run to 2055. The results after year 2000 have little to do with the coming reality. However, they tell something about the model structure. Because the model only includes primary

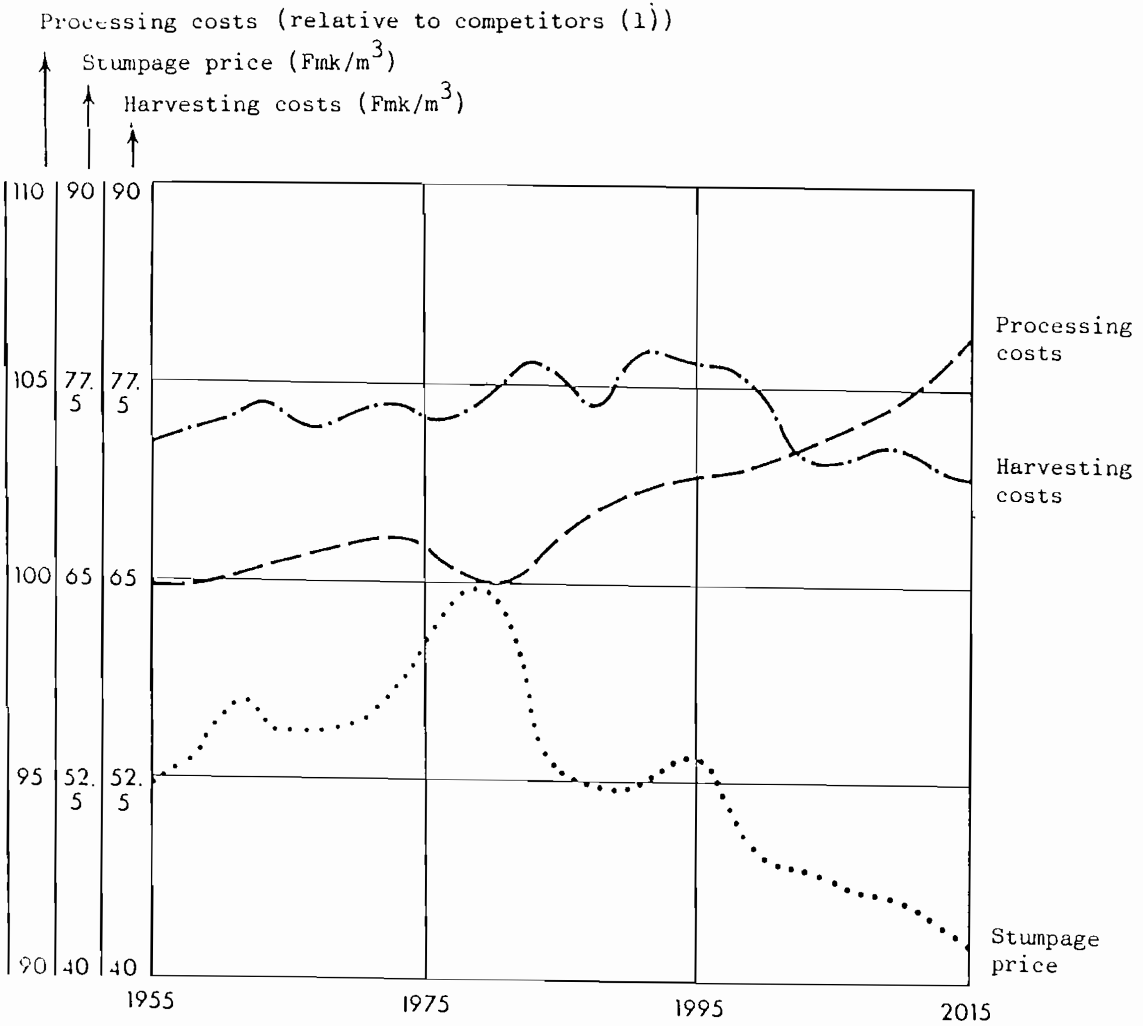


Figure 4.
<u>Processing costs</u> include variable production costs other than wood raw material costs. In the figure they are given relative to competitors whose processing costs are 100.
<u>Harvesting costs</u> give the costs of cutting, hauling, and transportation, plus overhead costs, all deflated with the export price index (1975=100).
<u>Stumpage price</u> is the average wood price on the stump (1975=100).

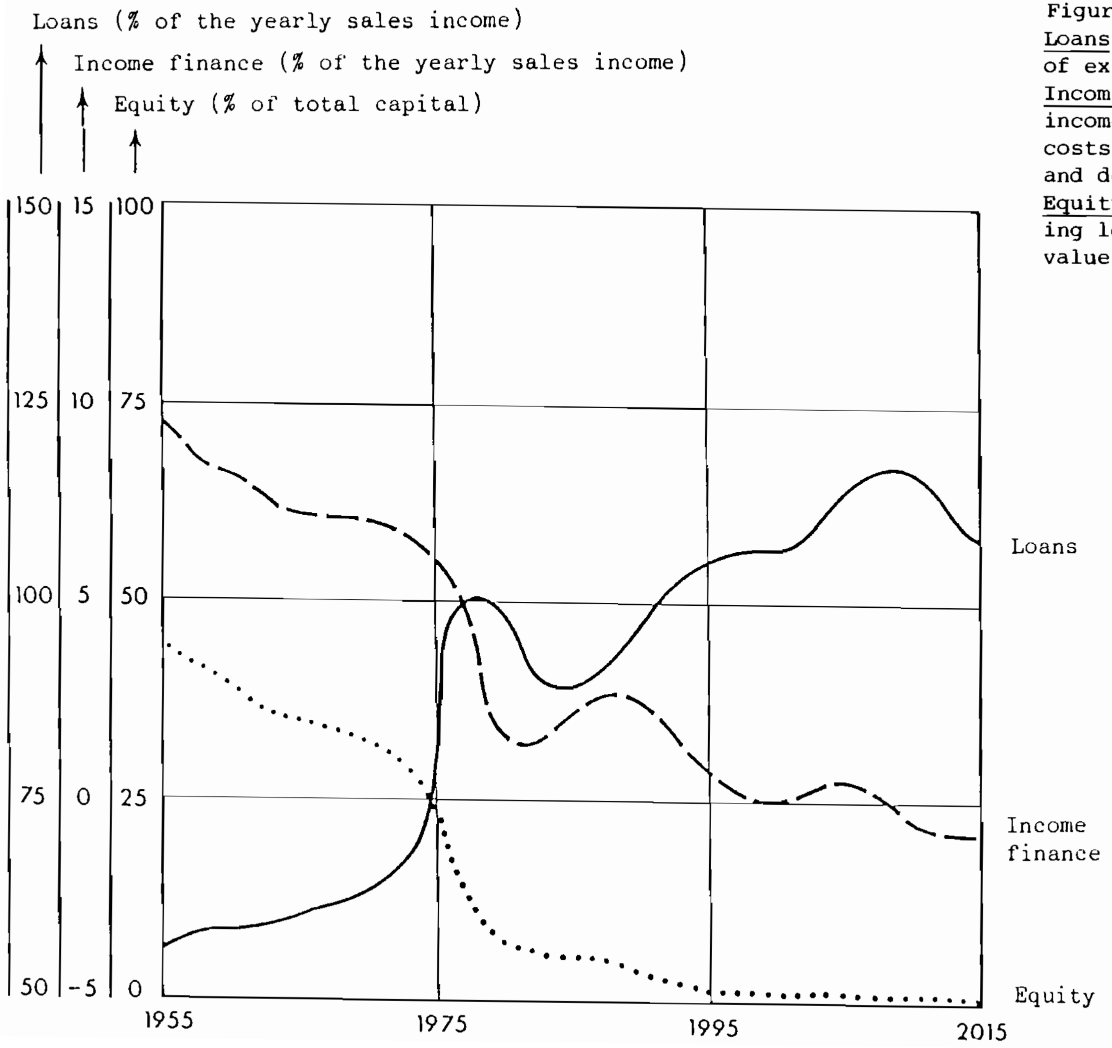


Figure 5.
Loans describe the total amount of external long term capital.
Income finance is the sales income minus variable production costs, interests, taxes, dividend and depreciation of loans.
Equity is obtained by subtracting loans of the total sales value of production capacity.

Figure 6

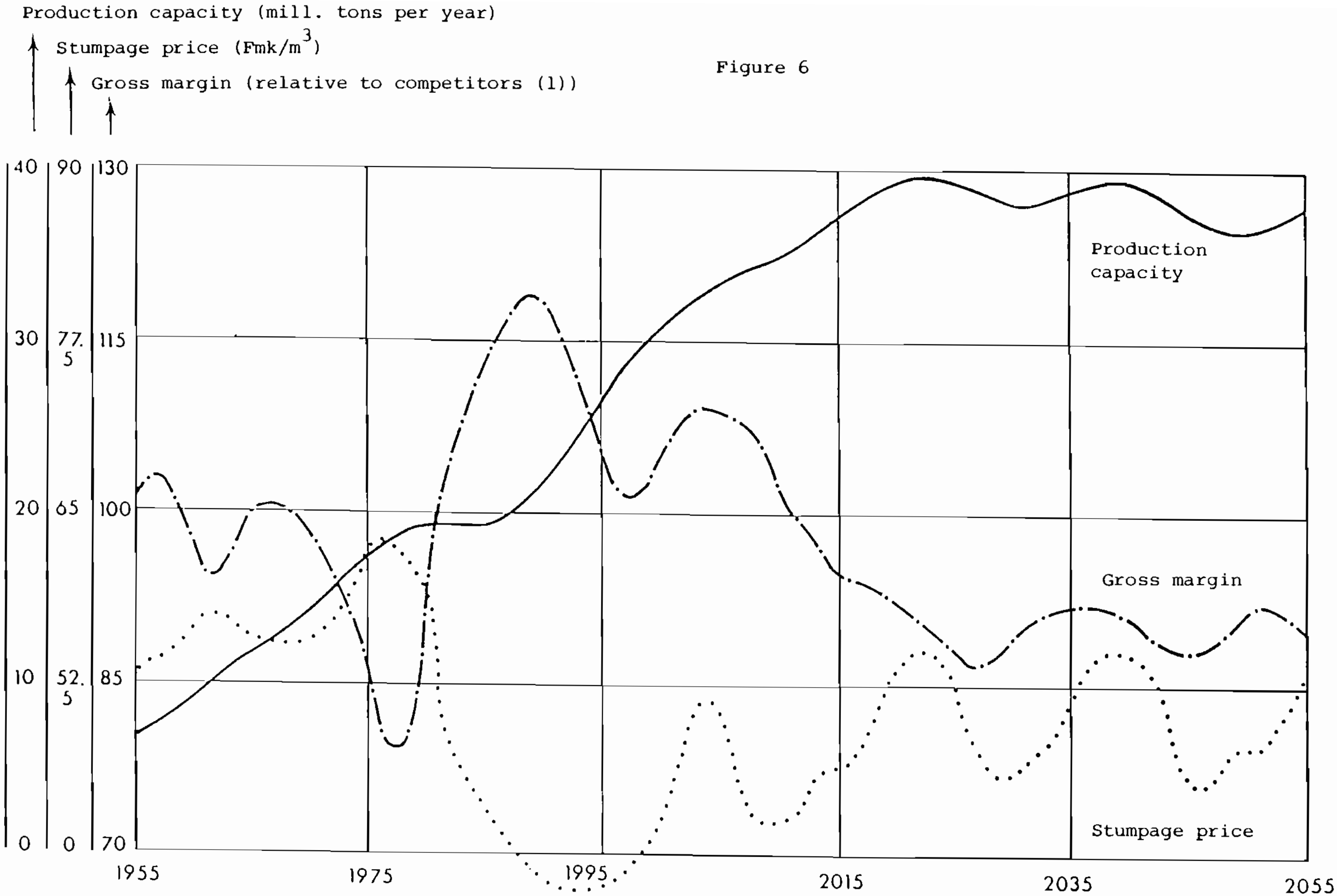
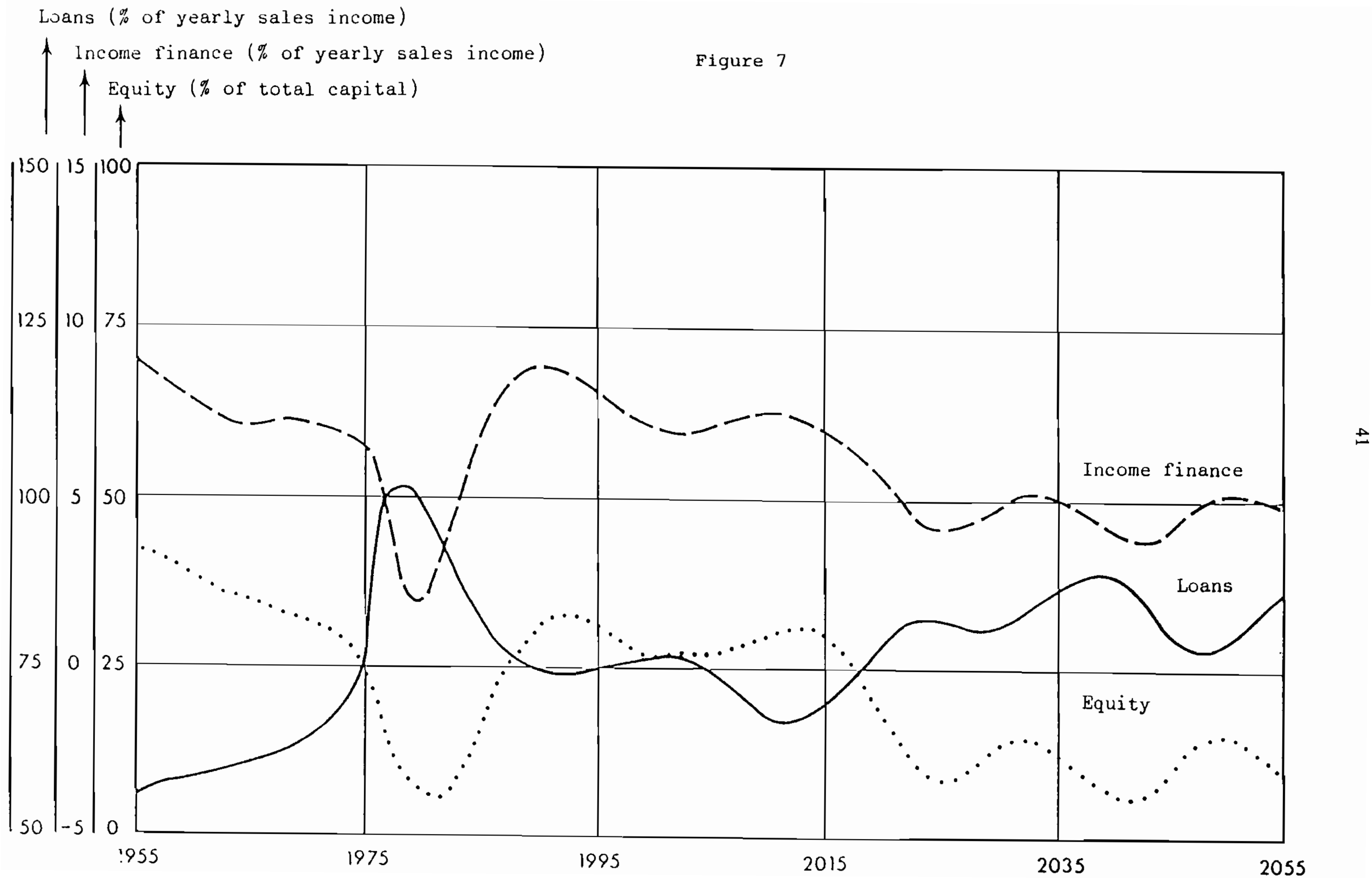

Production capacity (mill. tons per year)
Stumpage price (Fmk/m3)
Gross margin (relative to competitors (1))
40 30 20 10 0
90 77.5 65 52.5 0
130 115 100 85 70
1955 1975 1995 2015 2035 2055
Production capacity
Gross margin
Stumpage price

Figure 7



Loans (% of yearly sales income)
Income finance (% of yearly sales income)
Equity (% of total capital)
150
125
100
75
50
15
10
5
0
-5
100
75
50
25
0
1955
1975
1995
2015
2035
2055
Income finance
Loans
Equity

production, the physical raw material constraint will become effective sooner or later. In this run it happens after the year 2020. It is also interesting to note that the model produces 15-20 years investment cycles known as Kuznets cycles. These are especially visible after the year 2000.

CONCLUSION

The above two examples represent two extremes. The first shows that a passive laissez-faire mentality may have severe consequences. Even the better alternative shows how difficult it is to avoid the stagnation in capacity increase at the beginning of the 1980s. The most crucial factor is the financial situation of the forest industries. Also the human constraints in raw material availability should be properly taken care of if we do not want to waste the money invested in timber growing during the past two decades.

The discussion above concerns primary production. Further refinement is not tied to the raw material base in the same way. Also, raw material costs per unit of production can be considerably smaller than in the primary production. A sound financial situation is, however, equally important in further refinement.

Although further refinement is the strategic choice of the 1980s for the Finnish forest industry, we cannot change the situation over night. Primary production will keep its dominating role until the end of this century and its problems cannot be overlooked. Furthermore, it is difficult to imagine a profitable converted products industry in Finland without a sound primary industry.

WHAT WE NEED AND WHAT WE HAVE IN SWEDEN

Sten Nilsson, *

Abstract.-- This paper explores the present situation in the Swedish forest sector with regard to choices for a strategy in the future. At the outset this situation raises a requirement for analyses which must be carried out in order to consolidate the choices. This requirement is then set against those models used in the sector today. With this comparison is brought up a discussion about where it might be worthwhile to work with formalized models in different problem areas.

Additional keywords.-- Swedish forest sector, sectorplanning, operations research, fuzzy making decisions, stagnation stage.

INTRODUCTION

The title of this paper concerns concepts in alternative models of the Swedish forest sector. My intention is to derive from the present situation in Sweden, a choice of strategies for the future. From the existing situation I will try to identify which types of analyses and analysis instruments we need to implement in order to be able to guide development in a desired direction. I also intend to expose how our existing analysis instruments respond to this need.

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SWEDISH FOREST SECTOR IN A STAGE OF STAGNATION?

In the following I shall take up a number of points which suggest that the Swedish forest sector has been in a stage of stagnation for some years.

Wood availability

The forest industry had good possibilities for expansion, volume-wise, up to the middle of the 70's without any restriction from fiber supply.

We find however ourselves now in a situation where further expansion is impossible. This is caused by primarily two factors:

- The forest industry capacity expanded rigorously at the beginning of the 70's so that today there is a balance with respect to supply and demand in fibers.

- This situation is made dramatically worse since the supply from private forestry has diminished drastically since the middle of the 70's. This caused fiber imports to increase over the last five years.

It can be established that we now have reached a situation where there is a balance between supply and demand in fibers. This means that no competitive advantage can be gained over the next twenty years by increasing the volume of fibers harvested.

Wood Costs

The wood costs at the mill clearly reflect the forest resource case.

Wood costs increased dramatically in Scandinavia in 1974 because of a strong demand for forest products. The wood costs in Sweden is today twice as high as in US South and British Columbia. This illustrates quite clearly that Sweden will not be able to better its competitive position through low wood costs.

Technological Development

Technological development during the 60's and 70's in the industry have been directed toward further development of known technology towards larger and larger units within the pulp and paper industry. This development can be explained by the fact that the industry has choosen a strategy to reach the advantages in the economics of scale in bigger units. By following this philosophy previously, a competetive advantage could be maintained. The Swedish forest industry now finds itself in a position where further large advantages in economics of scale cannot be obtained from a competitive point of view.

We can construe that the Swedish forest industry cannot gain further extensive advantages through increasing economics of scale when it already approaches optimal size. Any implementation of an entirely new technology in operations is not to be expected in the next ten years.

Market Conditions

The most important market for Swedish forest industry products is Western Europe. Consumption of bulk products in this area has more-or-less stagnated, and this stagnation can be expected to continue for the rest of this century.

Market development in Western Europe, therefore, has put pressure on the Swedish forest sector to enter a stage of stagnation.

Saw timber Characteristics

According to opinion surveys given to leading importers of sawmill products in Western Europe, Sweden's strength has been in the high quality of her wood. However, in recent years the desired amount of the quality unsorted sawn wood has not been maintained.

The means by which Swedish forests have been managed has caused the undermining of the most important criteria - the high standard of standing timber destined - for the Western Europe sawn wood market.

Investment

Because of the interacting effects of market conditions, technological development, inflation, and general cost development, investment cost in the Swedish forest industry has increased explosively during the 70's.

The cost index for new investments in the pulp industry has grown faster than the general plant costs index. By studying the general plant costs index compared to the consumer price index, it can be understood that it is difficult to motivate investors and generate investment capital to the forest industry in Sweden. This difficulty is enhanced by the fact that capital charges and operating costs of new investments in the industry today is much higher than the sales prices on the market for different products. The marketprices cannot compensate such high investment costs.

Productivity in Swedish forestry

Previously I have shown that wood costs in Sweden are high compared to other countries. During the 60's and early 70's we could partially compensate for this through increased productivity. During the second half of the 70's this trend reversed to a reduction in productivity. See table 1.

Table 1. Yearly percentile changes in productivity (given in value added per hour) in the Swedish forestry.

	1965-70	1970-74	1974-79
Productivity (Value added per hour)	7.9	7.4	-1.1

The explanation for the above comparison is connected to, among other things, the fact that meachanization in the logging industry hasn't produced such great gains in efficiency during the latter part of the 70's as it did previously.

Price Leadership

Sweden has, during the 60's and 70's, consistententtly lost leadership in prices for various products on the Western European market. During the 80's it is expected that Sweden will not be the price leader for any wood product at all in Western Europe (Stanford Research Institute, unpublished). Thus Sweden must continually adjust to our foremost competitors actions.

Consequences of Stagnation

There are in fact other examples to support, this concept of a stagnation stage in the sector which are not included in this presentation.

The forgoing indicators have been known to the sector for about five years. Consequently, the industry has had the time to seek suitable strategies to adjust to, or dampen the effect ot the stagnation. What has the industry chosen to do under these circumstances? Unanimously, an isolation policy has been chosen. This can be illustrated in the following examples.

- when any other business sector approaches stagnation, it seeks to work together with other business sectors in order to gain complimentary positive effects. The forest industry has only sought engagement with other sectors either to secure sales of traditional products, or to maintain a steady supply of raw material, e g chemicals, for its traditional products.

- the industry has vigorously resisted all utilization of forest biomass as an alternative source of energy. Instead of seeing this as an alternative - for a limited time - it has been viewed as a threat to the industry during stagnation.

- in many instances the industry has stubbornly only considered its own interests when in fact the interests of other groups were involved. This conduct - maintaining the status quo - has caused the loss of the real decision making process (political) where community interests are largely concerned. An example of such an instance is the use of herbicides and insecticides.

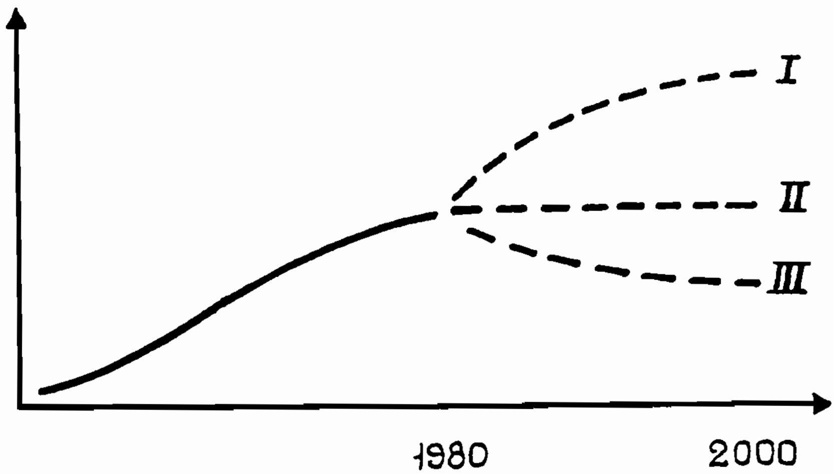
- a common trend in the industry is to shun diversification. One desires to strengthen one's position with those products one already handles.

- there are a number of companies within the industry which have registered quite large profits. Instead of investing these in projects involving some financial risks, they choose to withhold the capital without any yield, waiting for a convenient investment in the traditional sector that might provide a menial dividend of five or six percent after tax.

This chosen strategy also has consequences with regard to the industry's performance on the market. The large scale oriented technology, which of touched on earlier, affects considerably the value structure in an industrial company. Production oriented business ideas are derived from the values of effective refining processes, effective supply of raw materials, and effective distribution. Along with these ideas follows the desire to provide a homogenius supply and a standardized product. Production oriented competition requires that a consistant supply be accomplished by an even more standardized assortment. Business concepts which are production oriented lead to massive investments. They are, as previously mentioned, expensive and take a long time before the pay off. When a decision is reached concerning investment, it means the company's direction is committed for a long time to come. Also, the decision is often made with great risks. Should market conditions change so that there is no benefit from operating at full capacity, the investments are no longer profitable. A capital intensive means of production, and tight market prices create the need for employing a high capacity process. This in turn leads to a preoccupation with volume. The necessity to benefit from high capacity in the industry also causes companies in the forest industry to stabalize their operations by establishing secure relations with customers. When the basis for a production oriented company's ability to compete is threatened, it has bo turn to more market orientation. This switch in priorities is almost impossible to accomplish under such circumstances.

With the background given here we can say that Sweden has now to choose between three strategies concerning furture development in the forest sector. This is outlined below.

Degree of growth in the sector.



Choice of strategies for the Swedish forest sector

WHAT TYPE OF ANALYSES DO WE NEED FOR THESE DIFFERENT STRATEGIES?

Strategy 1

The point of this strategy is to find a new expansion phase to break the existing stagnation stage. The main goal of this strategy is to find a number of new business ideas. When seeking these new ideas it is necessary to regard the following guidelines:

Innovation	- to consider, whithout predjudice, all possible usages of the elementary components of a a forests' biomass. - in this contect it is essential to put great emphasis on functional economic analyses of fibers (and their constituant parts) characteristics in relation to other material. - with reference to the above, to try produce a number of possible products and lines of production development.
Research and Development	- in order to accomplish such activity it is necessary to seek interaction with other business sectors where research and development are superior to that in the forest sector
Financing	- further there must be a integration with other sectors where the initiative must be to gain mutual positive effect by working together. - integration with other sectors within, as well as outside the country, must be another result in order to broaden the financial base of the industry.
Marketing	- identify different trade obstacles to produce a transition to new lines of production development and to financial integration with other sectors within and outside the country. - work out programs of action for transition from production orientation towards market orientation. - intensify market analyses regarding supply and demand.
Consequenses for the business sectors	- point out the consequenses of a number of programs concerning the effects on the economics of the participating sectors, and the effects on the goals of the community concerned.
	⬇
Industrial policy	- using the results of these analyses formulate propositions to the politicians for an industrial policy that creates the desired interactions. Thereafter actively work towards implementing a suitable industrial policy.

Strategy 2

In this concept the industry must strive to hold established positions as long as possible for the more traditional directions in production. To succeed this strategy requires:

Innovation	- an active traditional product development. - the discovery of ways to increase the wood resource base. - the discovery of means to use fibers more effectively. Through for example integrating processes, combining processes, introducing new processes.
Research and Development	- considerable energy must be directed towards R and D concerning product development, possibilities for increased fiber production, increased harvesting from private forests, processes, which require less raw material.
Financing	- increased financial integration with the European Common Market. - increased secondary refining with the EC.
Marketing	- intensified market analyses concerning supply and demand in the long-term . - intensified market analyses concerning changes in the economic cycle. - try to dispose of existing difficulties in marketing. - transfer from production orientation to marketing orientation. - predictions for changes in various currencies both in long and short term.
Consequenses for the forest sector	- point out the consequenses of such a program, that is based on the above factors, for the sector's economy and the effects on the goals of the community concerned.
	⬇
The sector's policy	- together with politicians, formulate a sectorpolicy which is lacking today. This policy must allow a great flexibility so that a quick reaction to changes in the above factors can occur.

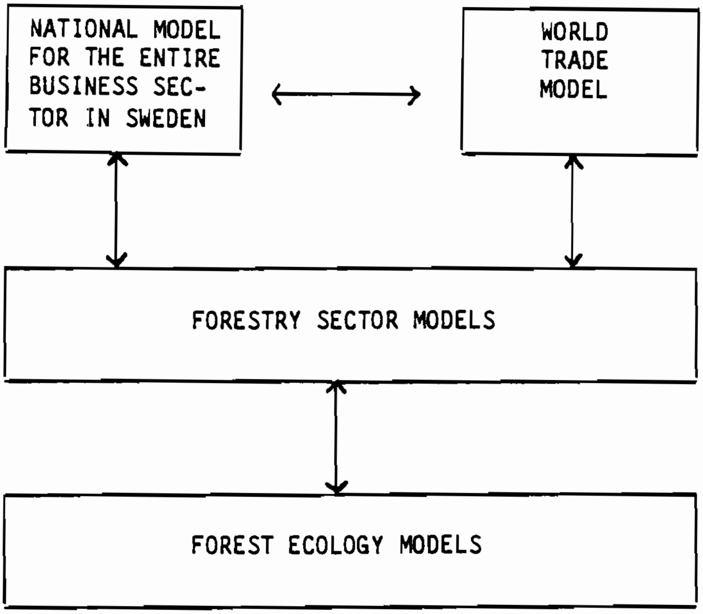
Strategy 3

This is a very pessimistic strategy where resources are transferred successively from the forest sector to other sectors. In this strategy it is important to find the optimal pace for reduction.

Innovation	
Research and Development	
Financing	
Marketing	- intensified market analyses concerning supply and demand - intensified market analysis concerning economic cycles.
Consequenses for the forest sector	- with reference to changes in the market, point out consequences of different reduction strategies for the sector and the community at large.
	⬇
The sector's policy	- together with the politicians, form a sector policy with a governed reduction strategy.

WHAT WE HAVE FOR MODELS IN SWEDEN

In the previous section, the necessity for analyses and instruments was presented. The models we possess that can be employed in these analyses are put together schematically below:



Different models for analyzing the forest sector in Sweden.

I shall now try to put models we possess in relation to the needs described in strategies one and two. I am also going to establish if it is possible to use rigid mathematical models (like input- - output models, L-P-models, system dynamics models, etc) to make the analyses where today we lack the instruments required to analyze the various strategies.

Strategy 1

Innovation

Within this problem area we have today no formalized analysis instrument in the systematic search for innovations. I find the possibility of applying rigid analysis models considerably limited in this connection. Consequently, a whole new methodology must be used. Within this area soft methods (fuzzy decision-making) are necessary to arrive at intelligent solutions.

Research and Development

In this field we also lack instruments for priorizing and linking different interesting research contributions. Even in this case I consider it almost impossible to build a formalized system-model for the presented and needed analyses. In connection with this the main thing is to identify individuals with interesting concepts, get them together, and make them aware of a central problem, in an attempt to genereate commitment. In this too, soft and intelligent methods are required.

Financing

Here we totally lack conventional analysis instruments. As for integration from a financial point of view the practical, real solutions will depend on the ability of individuals in different sectors to understand each others problems and to deal with diplomatic relations. From the aspect of research, the researchers will hopefully identify a number of interesting integration alternatives. However, even this must be accomplished with soft methods. When it comes to the point of choosing the right strategy, the decision will depend entirely on the above mentioned personal relations.

Marketing

Within the marketing area we have no conventional models that use the Swedish forest sector as a reference point. When it comes to regional trade difficulties and a transition towards market orientation, it would probably not be possible or meaningful to develope any conventional models. On the other hand, I believe the industry would benefit considerably if a model for market analysis were developed from the Swedish forest industry's standpoint. Thereby, the following needs should be fulfilled:

- we have to work with new methods for modelling the demand and supply situation

- we have to make projections for single products both in pulp, paper and sawnwood - and not for aggregates of products.

- we have to regard the aspects of quality with highest importance

- we have to concentrate the model on OECD-countries

- the model must be regionalized

- the financial aspects must be considered

- we have to make a distinction in the model between short term and long term projections.

- the quantitative data the model creates must be complimented with a system of qualitative data.

After having studied the models used by large consulting firms and the development work done by universities the world over in this area, I have come to the following conclusion. A further development of the system Adams and Haynes (7) have proposed for the U.S. should be the most fruitful in this connection.

Consequences for the forest sector

Within this area we can say we have three functioning systems or models. One model builds on the system-dynamic techniques (Lönnstedt (8)). The other two build on the L-P technique (Hultkrantz (9) and Nilsson (10)). The detailed model today of these two L-P models is being developed by the World Bank and is the IBRD forest sector model. It is that model with which I myself work and have further developed.

If the Swedish forest sector chooses strategy one, these models, after adjustments, should be worthwhile instruments for analyzing the consequences. It would probably not be possible to include all the effects on different welfare goals in the models. Therefore, even here rigid models should be complimented by a softer method in order to accomplish these various aspects.

Industrial policy

For developing an industrial policy, which we lack in Sweden today, there exists no formalized system at all. It would not be possible to impose any model for this purpose since the development of industrial policy is part of the democratic decision making process. In this process there is a form of bargaining between the business community, regional politicians, national politicians, various unions, and governmental departments.

Strategy 2

Innovation

Generally the same comments apply here as in Strategy 1. There is, however, one difference looking at the possibilities of influencing the level of harvesting in private forests as an innovation. During a number of years, we have worked within this area with different models to try to find a suitable formula to persuade the private forest owners to produce more wood (see for example, Löfgren (11) and Nilsson (12)). However, we cannot claim to be very successful. The reason being that the models have been to narrow and not been able to grasp factors like welfare-development and integration when it concerns the usage of the resource ground. In my opinion, however, a further development of the type of model produced by Clark Binkley created for the U.S. (13) might be a means for getting this question better analyzed in Sweden. It might then also be easier to find solutions to this problem.

Research and Development

See comments Strategy 1

Financing

See comments Strategy 1

Marketing

See comments Strategy 1 + concerning the analysis of the fluctuating economics of the marketplace for forestry products, we have a well functioning econometric model. This model was developed by Baudin (14) and after a couple of years of application we find it a valuable and powerful tool.

The development of currency fluctuation is of central importance to the economy of the Swedish forest sector over both long and short term. In this area we have not developed any models of our own because we cannot handle the extensive and rapid flow of information that is needed to develop such models. Certain business banks, however, have produced systems for monitoring monitary changes. Chase Manhattan, and the Marine Midland Bank of London are examples. I myself am connected to the latter banks world wide system MARINVU (15). The purpose is to try to make an assessment of the model system. The accuracy has proven to be good thus far for the twentyfour currencies employed in the system. However, there is a clear indication that if the drastic changes are to be grasped, the quantitative data has to be made complete by adding qualitative and political information.

Consequences for the sector

Under strategy 1 I mentioned that we have in Sweden three different model systems for analyzing consequences at the forest sector level. In connection with strategy 2 my intention is only to present the requirements that I consider need be fulfilled by a sector model for it to be used for relevant analyses. This list of requirements I put together is a result of a number of years experience dealing with sector analysis using the system of the World Bank. To be able to carry out relevant analyses of the forest sector requires that the model:

- is usable for several time-periods

- is regionalized

- can take into account a variable cuttingoptions from the resource forest.

- deals with every unique industry as a separate unit

- can analyze more than one goal function simultaneously, examples of such goal functions are.

i the industry's contribution to the GNP

ii the industry's contribution to the terms of trade

iii maximizing profit

iv maximizing employment in the sector

- should be able to consider alternative usages of the forest's biomass.

- can handle the financial aspects of the sector.

Sector policy

See comment Strategy 1

CONCLUSIONS

The purpose of this paper has been to show - from experience in the field - in which situations it is possible to use rigid system - analytical models in the forest sector, which is the theme of this congress.

a) First of all I would like to point out that it is important to identify very clearly in which decision situation the forest sector is in before starting to build models. I have, of course, simplified the case by stating that the Swedish forestry sector must choose between strategies 1, 2 (or 3). In reality it probably needs a mixture of them. However, I will emphasize how important it is to understand the situation the industry is in and the choices before it, in advantage working with rigid models. Only when this has been accomplished can a model which properly corresponds to all aspects of the problem be chosen.

b) Secondly, I would like to show in this paper that we can really only use mathematical models effectively when the frame of reference - destination - is fairly clearly defined ahead of time. However the direction must be decided using softer methods.

Because of this mathematical models within the sector will only be at their best when analyzing different alternatives for estimating results.

From this we can also say that the possibilities of solving the problem using models is limited within the sector. They are, however, a part of the solution to the problem.

c) Using this paper as a background the listener - reader - might get the impression that I am sceptical towards all mathematical models. This is not the case, but I mean the models should be used in their proper context and not as a kind of patent medicine.

Furthermore, it has been my experience that often it is not until the models are used that you can quantify the problem in physical and monitary terms so that the problem can be engaged by the sector. This applies to, among others, politicians, union people, and managing directors.

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CONCEPTS USED IN A REGIONALIZED MODEL OF PULP AND PAPER PRODUCTION AND TRADE

Joseph Buongiorno and James K. Gilless[1]

Abstract.--This paper outlines the structure and underlying concepts of a model of the pulp and paper sector to be used in the 1985 U.S. Forest Service Timber Assessment. This multi-regional partial equilibrium model is designed to calculate equilibrium prices and quantities in the various regions during each year of the projection period. The model combines econometric estimates of all final demand and some supply relationships with a detailed input-output representation of technological processes in the regions of major interest. Econometric and activity-analysis relationships are combined in a separable programming model which yields short-term equilibrium solutions by maximizing net social pay-off. Long-run changes in regional capacity and technology are guided by profitability of installed capacity. The linkages with other models of the 1985 Timber Assessment study are described.

Additional keywords: pulp and paper, regional models, mathematical programming, supply, demand, forecasting.

INTRODUCTION

The Renewable Resources Planning Act of 1978 requires the United States Forest Service to make periodic assessments of long-term supply and demand of forest resources in the country. In the latest (1980) assessment of this kind, long-term projections were made for the first time not only of timber consumption and production, but also of equilibrium prices. This was done thoroughly for the softwood lumber and plywood sector, based on the softwood Timber Assessment Market Model (TAMM, Adams and Haynes, 1980). However, for lack of resources, the same was not done for the pulp and paper sector. It has since been decided that the 1985 Assessment should be based in part on a model of the pulp and paper sector with the following characteristics: Prices should be endogenous, reflecting the balance between supply and demand forces in the sector. The model should reflect the regional character of the industry, and appropriately depict the international setting in which the industry is competing. The model should represent the various technical processes which can be used to make paper, their evolution over time, and their selection under different economic conditions. Most importantly, the model should be able to depict the regional shifts of manufacturing capacity as a result of the supply and demand conditions in various regions, especially

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with regard to the availability of pulpwood and other fibers. Finally the model should be designed in such a way that it could be linked with the rest of the Timber Assessment Market Model, so as to reflect the interrelationships between the solid wood and the pulp and paper subsectors.

The purpose of this paper is to outline the structure of a model which satisfies those requirements. The model is currently being developed and no run has yet been done with real data. The paper thus necessarily deals with concepts rather than with applications.

MODEL OUTLINE

In past forecasts of the pulp and paper sector it was generally agreed that income and population growth were the primary determinants of future paper and paperboard demand (FAO, 1960; Hair, 1967). Once conditional forecasts of demand for final products were obtained, the corresponding pulp and wood requirements were calculated by various conversion factors. Even if cost minimization was attempted for the industry (Bergendorff and Glenshaw, 1980; Colletti and Buongiorno, 1980; Svanqvist, 1980) demand was still assumed to be exogenous. This approach may have seemed adequate during the 1950-1970 era while paper and paperboard prices were declining in real terms. Since the oil embargo of 1973, however, paper and paperboard prices have more than doubled. This trend may well continue due to the importance of energy and capital costs in that industry (Buongiorno and Gilless, 1980). Increasingly it has become apparent that a model of the pulp and paper sector must allow for price-induced decreases in demand. This is further supported by econometric studies which have indicated highly significant elasticities of paper and paperboard demand with respect to prices (Buongiorno, 1978; Buongiorno and Kang, 1981).

The introduction of price-responsive demand functions also has implications for supply. Other things being equal, a shift in demand which might occur from population or real income growth would lead to a rise in real price. At higher prices, more paper and paperboard would be produced. Price and quantity are therefore interdependent. One cannot be projected in isolation from the other. This provides the motivation for the partial equilibrium model used to describe the pulp and paper sector. The equilibrium is only partial in that many variables, such as income and energy prices are treated as exogenous.

The partial equilibrium model of the pulp and paper sector is illustrated by Figure 1. This figure refers to a single commodity in a single region. In the actual model there are as many quantities and prices as there are commodities and regions. Consumers' willingness to pay (demand) is shown as a decreasing function of the quantity available, while producer's incremental costs (supply) are shown as an increasing step-function of the amount produced. In the model, each demand function is based on econometrically-estimated elasticities. Supply is represented instead by a detailed description of various paper making technologies, as well as by econometric functions.

Supply and demand are integrated by a mathematical programming algorithm. The objective function is the sum of consumer surplus and producer surplus, which corresponds to the area between the demand and supply curves in Figure 1. Maximization of consumer plus producer surplus leads to an equilibrium price, P_t^E, and a corresponding quantity, Q_t^E, at which consumers' willingness to pay matches the producers' cost of production. The algorithm thus simulates the workings of a competitive pulp and paper sector.

The optimization procedure just described is used to calculate equilibrium prices and quantities for all commodities being produced, transported and consumed within the pulp and paper sector in any given year during the projection period. However, it is recognized that long-term decisions within a decentralized industry can be less than optimal. This is due to imperfect forecasts and to the inability of the industry to immediately adjust to changes. This is especially relevant for capacity expansion which requires several years.

In this model it is assumed that capacity expansion in the entire industry is a distributed-lag function of past sales, and of the profitability of existing capacity in the various regions. Profitability is measured by the shadow price of a unit of capacity for a specific process in a given region when the short-term optimization problem described above has been solved.

The evolution of the pulp and paper sector described by the model is represented by Figure 2. The demand and supply situation in year t is the same as was represented in Figure 1. Maximization of consumer surplus plus producer surplus in that year leads to the equilibrium price and quantity P^E_t, Q^E_t. The results of that solution, especially the shadow prices for capacity, and exogenous shifts lead to a new supply and demand system described by D_{t+1} and S_{t+1}. Optimal allocation of resources during year t+1 leads to new equilibrium prices and quantities P^E_{t+1}, Q^E_{t+1}. The process is continued until the forecast horizon is reached. This combination of short-term optimization and imperfect foresight in capacity expansion is similar to the recursive programming approach widely used by Richard Day and his students (Day, 1973; Abe, 1973; Nelson, 1973). The main difference arises in that while Day assumes that the decision to produce is based on current, exogenous prices this model assumes market clearing prices in any given year with both prices and quantities being endogenous.

COMMODITY AND REGIONAL DETAIL

The model can accomodate as many regions as desired, within the limits of computer capacity. For the 1985 Assessment study the United States will be divided in eight supply regions and six final product demand regions, identical to those used by the TAMM model (Table 1). Current plans are to divide Canada into three regions, to consider Western Europe and Japan as two separate regions, and to group the rest of the world into a single region. Manufacturing in the U.S. and Canada is described in some detail via activity analysis, while supply from other regions is only sketched with econometric relationships as indicated below.

For purpose of the Assessment study the model uses twelve aggregate commodities, listed in Table 2. Raw materials consist of softwood and hardwood pulpwood and mill residues, and of recycled paper and paperboard. Intermediate products consist of mechanical and chemical pulp. Final products are classified into newsprint, printing and writing paper other than newsprint,

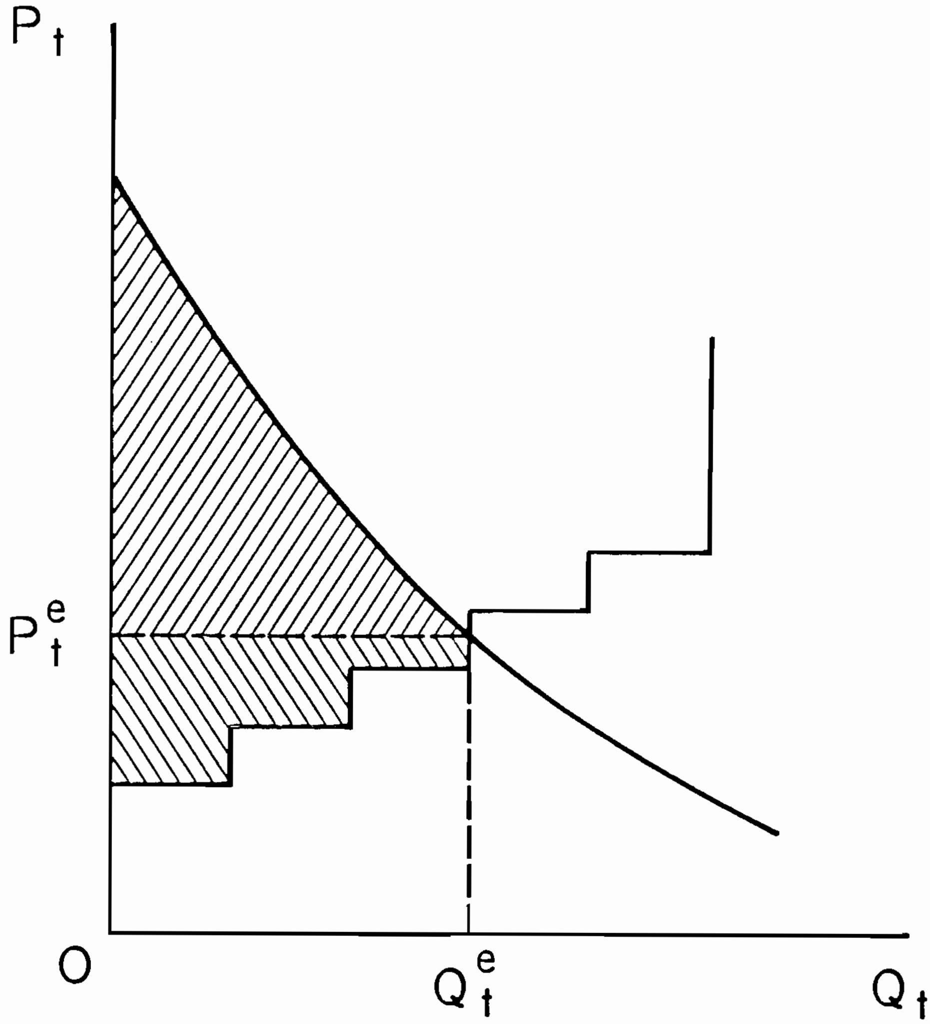

Figure 1 Short-term equilibrium calculated by the model by maximizing net social pay-off (gray area).

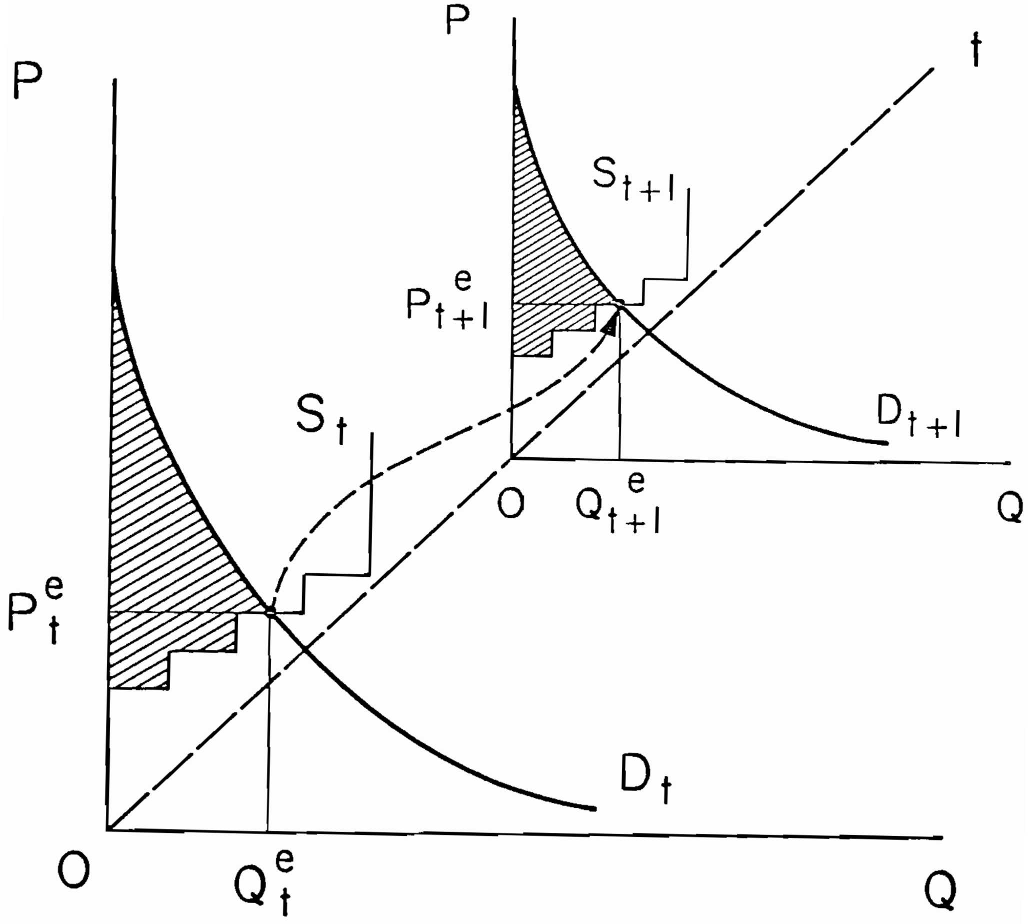

Figure 2 After predicting shifts in demand and supply from exogenous factors and from the equilibrium solution in year t, a new solution is computed for the year t+1.

Table 1: Regions used by pulp and paper model.

	Supply	Demand
1. United States		
	Pacific Northwest-West	Northwest
	Pacific Northwest-East	Southwest
	Pacific Southwest	North Central
	Rocky Mountains	South
	North Central	East
	North East	
	South East	
2. Canada		
	Western Canada	id.
	Central Canada	id.
	Eastern Canada	id.
3. Western Europe		id.
4. Japan		id.
5. Rest of the world		id.

Table 2: Commodities used by pulp and paper model.

1. Raw materials
   - Softwood
     - Pulpwood
     - Residues
   - Hardwood
     - Pulpwood
     - Residues
   - Paperstock
     - Newsprint
     - Other printing and writing paper
     - Other paper and paperboard
2. Intermediate products
   - Mechanical pulp
   - Chemical pulp
3. End products
   - Newsprint
   - Other printing and writing paper
   - Other paper and paperboard

and other paper and paperboard. This list may be expanded or reduced depending on the purpose of the study, data availability and computing capacity.

MATHEMATICAL PROGRAMMING STRUCTURE

The short-term optimization problem which the model solves every year to describe short-term market mechanisms is formulated as a mathematical programming problem. Non-linearities arising from the inclusion of price-responsive demand functions are treated by the separable programming technique proposed by Duloy and Norton (1975). The model expands this idea to the supply side to reflect price-responsive supply of domestic or imported commodities. Therefore the model combines optimization and econometric techniques to represent the pulp and paper sector. Demand and supply relationships which can be modeled with some detail are represented by technical input-output coefficients, while those which cannot are represented by supply or demand econometric functions. The two are linked by the objective function which measures producer plus consumer surplus, to be maximized.

More specifically, the static model referring to any given year is represented by the following groups of relationships. The mathematical formulation is outlined in the Appendix.

1) The price-responsive supply relationships state that the quantity of a commodity supplied by a region must balance the quantity transported from that region to other regions. There is one constraint of this type for each commodity and region in which supply is specified explicitly as a function of price. This is the case of the supply of all primary materials: pulpwood and recycled paper. This representation of supply is also used for commodities and regions for which a detailed representation of supply is not possible or desirable.

Note that in the Assessment model the supply of pulpwood in year t is defined by the price of pulpwood in the previous year, up to a maximum supply. This facilitates the linkage with the remainder of the Timber Assessment Model, as described below.

The maximum supply of recycled paper is a fraction of last-year's consumption, defined by technical considerations. Within that maximum, supply is a direct function of price.

2) The manufacturing input-output equations express the fact that the raw materials received by a region in which a commodity is manufactured are directly proportional to the quantity produced. The input-output coefficients describe various techniques of production. For example, newsprint can be made from virgin pulp alone, or from some mixture of virgin pulp and recycled fiber. The model selects the cheapest combination. There is one constraint of this type for each commodity in a region that serves as an input to one of the detailed manufacturing processes in that region.

3) The manufacturing capacity constraints state that the amount of a commodity made in a region according to a particular process is limited by the existing capacity in the year being considered.

4) The shipment equations express the balance between the production of each commodity in each region and shipments to other regions.

5) The price-responsive demand equations refer to the equality between the amount of a commodity transported to a region and the amount demanded in that region. There is one such constraint for each region and commodity for which demand is modeled as a function of price. This is the case for all paper and paperboard commodities. It also applies to the demand for pulpwood and pulp in regions where the use of these inputs is not modeled in detail.

6) The objective function measures total consumer plus producer surplus in the forestry sector in a given year. This function which must be maximized consists of: the area under all demand curves, which expresses the value to consumers of all the commodities they have bought; minus the area under all supply curves, expressing the cost of all materials supplied; minus the cost of manufacturing, excluding the cost of materials explicitly considered in the model and the cost of transportation; minus all transport costs.

Thus, the maximized quantity is the sum of producer surplus plus consumer surplus, i.e., the shaded area in Figure 1, which Samuelson (1954) calls the net social pay-off.

DYNAMIC CONSIDERATIONS

The optimization model just outlined describes the short-term equilibrium defined for a specific year in the pulp and paper sector given a fixed level of capacity and a certain position of all demand and supply curves in the price-quantity plane. Modeling changes from one year to the next involves modeling capacity expansion in the various regions as well as demand and supply shifts.

Capacity is measured by commodity, process and region. When the short-term maximization problem described above is solved, the dual solution yields a set of shadow prices which measure the value of one additional unit of capacity for each commodity, process and region. Total capacity expansion for one commodity (for all regions and processes collectively) is a distributed lag function of past sales, estimated econometrically. This total capacity expansion is then distributed by region and process. The allocation function is such that capacity is expanded only for regions and processes whose shadow price is higher than the cost of capacity expansion, and expansion is higher for those regions and processes with higher shadow price.

Demand shifts from year t to t+1 are determined in a straightforward manner from the income elasticities as well as from exogenous estimates of income and population growth in each region of interest.

Supply shifts are in part due to changes in costs which are not determined endogenously by the model. These include the cost of all inputs in manufacturing processes, excluding the cost of materials explicitly recognized by the model; i.e., pulpwood, pulp and other fibers. Supply shifts may also be due to technological change. This can be represented in two ways in the model. The simplest is to change input-output coefficients of the technology matrix, for example, to reflect higher fiber recovery within an existing process. The effect of a totally new process can also be modeled by introducing a new activity when the innovation is expected to occur. The growth of this new technology is then represented in the same manner as the growth of existing capacity; i.e., as a function of its relative profitability.

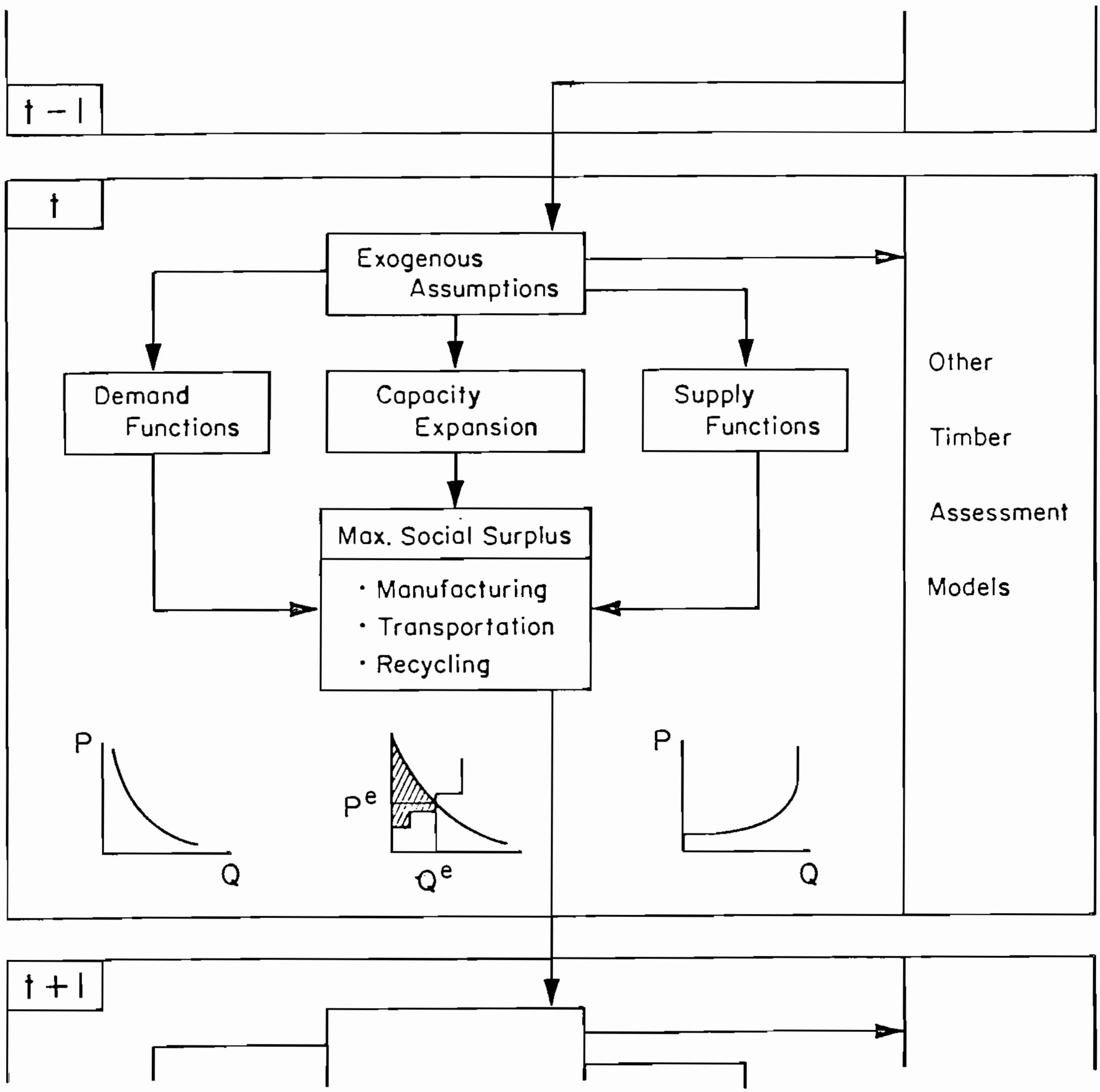

Figure 3 The pulp and paper model provides information to the other Timber Assessment models and receives information from them within a simulated one-year delay.

LINKAGE WITH THE SOLID WOOD SECTOR AND FOREST GROWTH MODELS

The link between the pulp and paper model described here and other models used in the 1985 Assessment consists of the common exogenous assumptions and of the pulpwood and pulp quantities and prices. Solution of the pulp and paper model for year t depends, among other things, on the price of pulpwood in year t-1 and on the quantity of residues produced by the solid wood sector in year t-1. The equilibrium quantities of pulpwood consumed in year t and the price of pulp determined by the pulp and paper model are used in conjunction with the growing stock model of TAMM to predict the price of pulpwood in year t+1. The process is repeated until the end of the projection period. Figure 3 illustrates this iterative process. It shows that the pulp and paper model and the sectoral models of the TAMM study are not solved simultaneously at each point in time. However, the solution of year t obtained by one model is provided to the other model to compute the solution for year t+1.

It is believed that this is a sufficient approximation of reality for a model which is designed to produce forecasts of up to 50 years and not precise year-to-year fluctuations. On the other hand, this approach greatly simplifies the modeling work. It allows each team assigned to a particular sector to freely design the model which is most appropriate for that sector, as long as it provides the information needed by modelers working on another sector.

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Appendix: Equations and constraints in the pulp and paper sector model.

The equations and constraints which define the pulp and paper sector model are listed below with descriptive titles. Some equations, particularly those adapted from the separable programming methodology of Duloy and Norton (1975), are suppressed in the interests of brevity. All symbols are defined in Table 3.

(1) Price responsive supply relationships:

$$S_{ik} - \sum_{j \in J_{ik}} T_{ijk} = 0 \qquad k \in IC,\; j \in IR_1$$

(2) Recycling maximums:

$$S_{ik} \leqq C_{-1ik} * R_{ik} \qquad k \in IC^r,\; i \in ID^r_k$$

(3) Manufacturing input-output equations:

$$\sum_{i \in I_{jk}} T_{ijk} - \sum_{\substack{l \in IM_j \\ p \in IP_{jl}}} A_{jklp} * Y_{jlp} = 0 \qquad k \in IC,\; j \in IR_1$$

(4) Manufacturing capacity constraints:

$$Y_{jkp} \leqq K_{jkp} \qquad k \in IC,\; j \in IR_k$$

(5) Shipment equations:

$$Y_{ik} - \sum_{j \in J_{ik}} T_{ijk} = 0 \qquad k \in IC,\; i \in IR_k$$

(6) Price responsive demand relationships:

$$\sum_{i \in I_{jk}} T_{ijk} - D_{jk} = 0 \qquad k \in IC,\; j \in ID_k$$

(7) Definition of total production:

$$\sum_{p \in IP_{ik}} Y_{ikp} - Y_{ik} = 0 \qquad k \in IC,\; i \in IR_k$$

(8) Objective function:

$$\text{maximize } Z = ZCPS - ZM - ZT$$

(9) Interperiod shifts in manufacturing costs:

$$CM_{+1ikp} = c_{ikp} * CM_{ikp} \qquad k \in IC,\; i \in IR_k,\; p \in IP_{ik}$$

(10) Interperiod shifts in transportation costs:

$$CT_{+1ijk} = c_{ijk} * CT_{ijk}$$

$k \in IC$
$i \in I_{jk}$
$j \in J_{ik}$

(11) Manufacturing capacity change:

$$K_{+1ikp} = K_{ikp} + \sum_{t=0}^{3} U_{-t} * A_{-t} * (S_{-tk} - S_{-t-1,k}) - D * K_{ikp}$$

$$U_{-t} = Z_{-tikp} / \sum_{i} \sum_{p} Z_{-t-1,ikp}$$

$$Z_{-tikp} = 0 \text{ if and only if } Z^{o}_{-tikp} > Z_{-tikp}$$

$k \in IC$
$i \in IR_k$
$p \in IP_{ik}$

Table 3: Definitions of symbols used in constraints and equations.

Symbol	Definition
IC	set of commodities
IS_k	set of regions in which the supply of commodity k is price responsive
ID_k	set of regions in which the demand for commodity k is price responsive
I_{jk}	set of regions which can supply region j with commodity k
J_{ik}	set of regions which can be supplied with commodity k from region i
IM_i	set of commodities in region i for which manufacturing is modeled as an input-output process
IP_{ik}	set of production processes by which commodity k can be produced in region i
IR_k	set of regions in which the manufacture of commodity k is modeled as an input-output process
IC^r	set of recyclable commodities
ID^r_k	set of regions in which commodity k may be recycled
S_{ik}	quantity of commodity k supplied by region i
D_{ik}	quantity of commodity k demanded by region i
T_{ijk}	quantity of commodity k transported from region i to region j
Y_{ik}	quantity of commodity k produced in region i
Y_{ikp}	quantity of commodity k produced in region i by process p
A_{jklp}	unit input of commodity k in the production of commodity l by process p in region j
C_{-1ik}	quantity of commodity k consumed in region i in the previous year
R_{ik}	maximum fraction of commodity k that can be recovered for recycling in region j
D	yearly rate of depreciation in capacity
Z	value of objective function
ZCPS	sum of consumer and producer surplus
ZM	sum of costs of production in input-output processes
ZT	sum of costs of transportation
CT_{+1ijk}	cost of transportation of commodity k from region i to region j in year t+1
c_{ijk}	rate of growth of transportation cost for the transportation of commodity k from region i to region j
CM_{+1ikp}	cost of manufacturing commodity k in region i by process p, excluding wood and pulp costs, in year t+1
c_{ikp}	rate of growth of the cost of manufacturing commodity k in region i by process p
K_{ikp}	current capacity of production for commodity k in region i by process p
K_{+1ikp}	capacity of production for commodity k in region i by process p in year t+1
Z_{-tikp}	shadow price for capacity of production for commodity k in region i by process p, t years ago
Z^o_{-tikp}	cost of capacity expansion for production of commodity k in region i by process p, t years ago
A_t	effect of sales changes t years ago on current capacity expansion
S^t_{-tk}	total sales of commodity k, t years ago

Modeling the Hardwood Sector: Issues and Prospects

Clark S. Binkley*
Peter C. Cardellichio**

In 1976 hardwoods occupied nearly half the U.S. commercial timberland, comprised 39% of the nation's timber inventory, and accounted for almost 30% of all wood consumption. Compared to the commercially more significant softwoods, little attention has been focused on modeling supply, demand, prices and timber inventory development of hardwoods. This paper discusses some of the considerations important to improving economic models of the hardwood sector.

This paper is intentionally and necessarily preliminary in nature. Because the hardwood sector is relatively less studied than the softwood sector, it is prudent to begin the modeling exercise with a critical examination of the important interactions in the hardwood sector, rather than simply adopting the structural framework developed over many years for softwood markets. Our initial focus has been on the stumpage sector, although we have not examined in any detail the adequacy of extant inventory projection methods.

Five sections complete this paper. The first discusses the character of hardwood final product markets--industry structure, and general trends in product outputs and prices. The second section extends this treatment to the hardwood timber resource. The third section examines the importance of log and lumber quality to modeling the hardwood sector. The fourth section explores the problem of linking final product demand to removals from the inventory. The final section summarizes the major challenges in developing a hardwood sector market model.

1. The Final Product Sector

Aside from Mead's classic analysis of the Douglas Fir industry, little research has considered the structure and organization of the U.S. forest products industry. One standard method for analyzing competition in an industry in to examine the influence of the largest producers. Table 1 presents some pertinent concentration ratios of selected segments of the

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TABLE 1

Concentration Ratios for Solid Wood
Products Producers, 1977

			Percent of Value of Shipments Accounted for By:			
		Industry	4 Largest Companies	8 Largest Companies	20 Largest Companies	50 Largest Companies
SIC	24211	Hardwood Lumber, Rough and Dressed	10	15	24	36
	2426	Hardwood Dimension and Flooring	14	19	31	46
	24212	Softwood Lumber, Rough and Dressed	21	29	45	61
	2435	Hardwood Veneer and Plywood	27	39	56	73
	2436	Softwood Veneer and Plywood	36	51	69	87

Source: Census of Manufacturers, 1977

TABLE 2

	Roundwood Removals by End Use, 1976 (bcf)			
	Hardwood		Softwood	
	Volume	Share(%)	Volume	Share(%)
Total	2.92	100.0	8.66	100.0
Lumber	1.03	35.3	4.57	52.8
Pulp	1.15	39.4	2.54	29.3
Plywood	0.10	3.4	1.18	13.6
Fuelwood	0.42	14.4	0.11	1.3
Misc.	0.22	7.5	0.26	3.0

Source: USDA (1980)

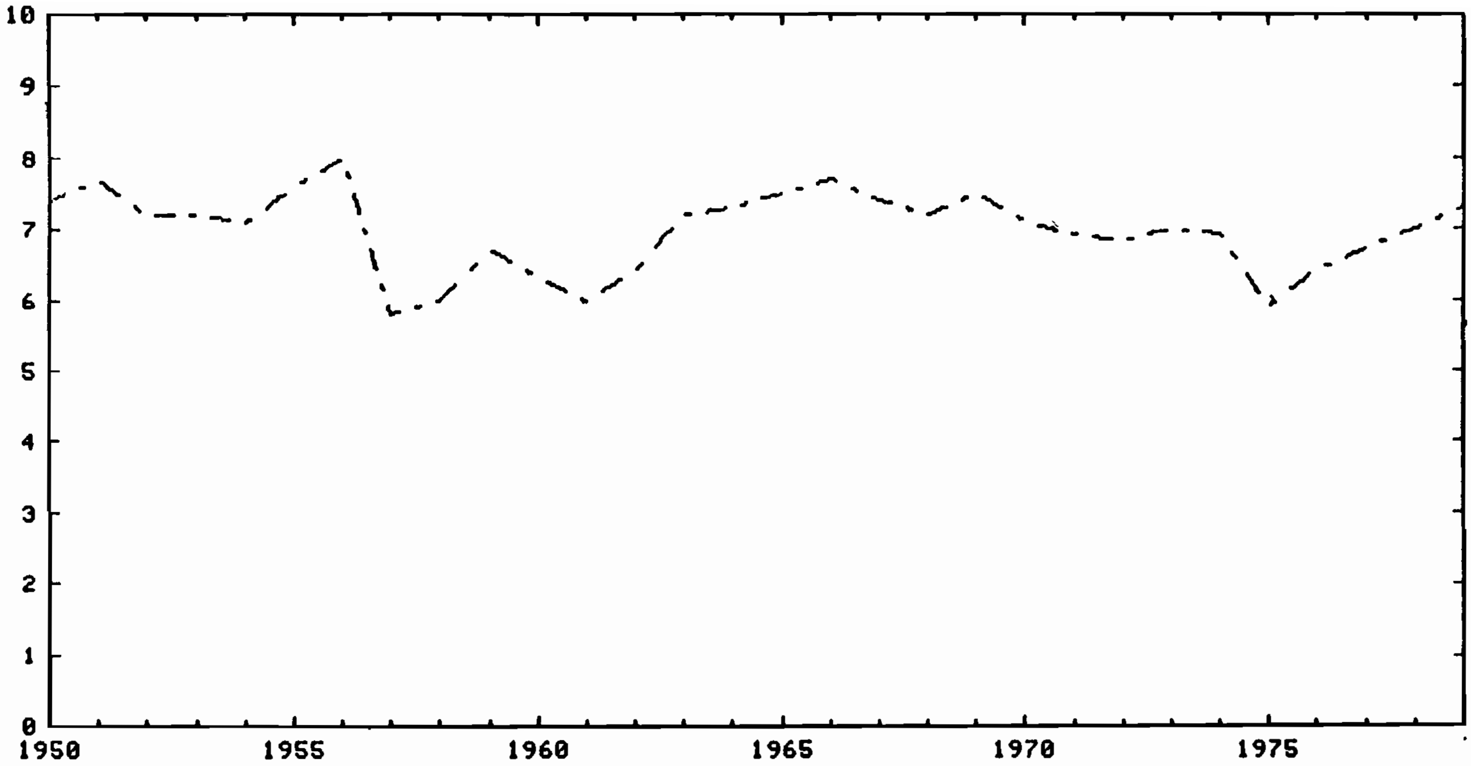

Figure 1 Hardwood lumber production (bbf).

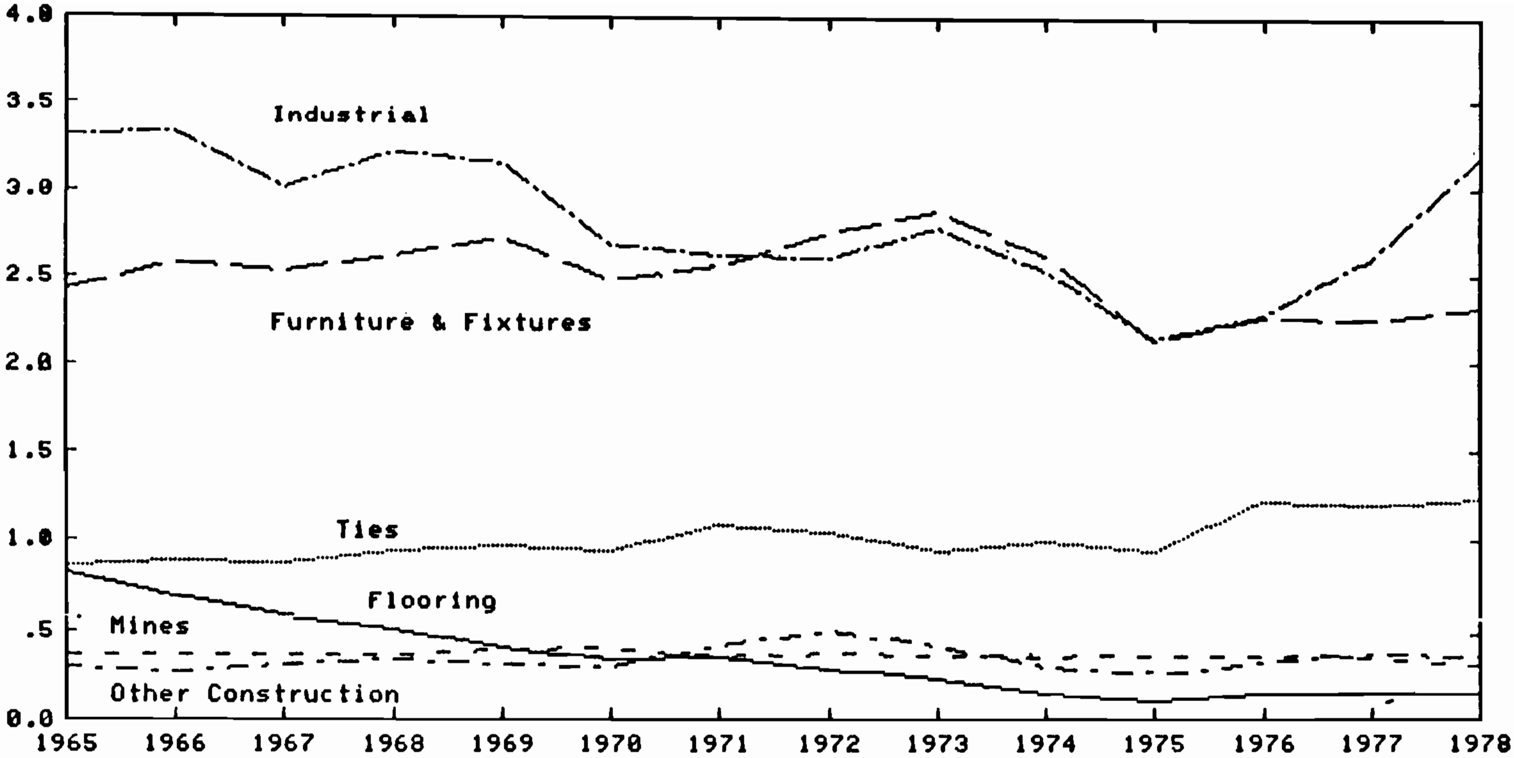

Figure 2 Lumber consumption by end use (bbf).

forest products industry. These measures of concentration suggest that the hardwood lumber and plywood industries are more competitive than their softwood counterparts. For example, the 1977 Census of Manufactures indicates the 20 largest hardwood companies originated only 24% of the total value of hardwood lumber shipments (SIC 24211), where the 20 largest softwood producers originated 45% of the softwood lumber value shipped.

Table 2 shows the relative importance of broad forest products classes in the hardwood and softwood sectors. Pulp and fuelwood are comparatively more important to the hardwood sector, and solid wood products less important. Hardwood pulpwood will be handled by a separate part of the timber assessment process and must be integrated into the hardwood assessment model, but will not be discussed further here.

The fuelwood market has apparently grown rapidly in recent years, and may become substantially more important in the future. Broadly speaking there are three principal users of wood for energy: residential users, partially or wholly wood-fired generating facilities in electric utilities or in commercial applications, and the forest products industry. While estimating the extent of the first two uses is difficult, it should be possible to drive a model of fuelwood use by the forest products industry off estimates of pulp, paper and solid wood products capacity along with estimates of the penetration of wood energy as a fraction of total energy use.

Lumber production accounts for nearly all of the hardwood solid wood products industry, although veneer products may carry higher unit values. Figure 1 shows that total hardwood lumber production has been roughly stable since 1950, averaging about 7 billion board feet annually. The lumber production data show substantial sampling errors when disaggregated to the regional or state level which raises concern about their suitability for model development. In addition some of the state data display apparent anomalies (lumber production rising during recessions, for example). Economists working at the NFPA have found that in some years the southern pine lumber production data from this source apparently understate by at least 20% total sawmill output. Because the hardwood lumber production are collected in a manner similar to the softwood data, we might expect comparable errors. We return to these problems below in the discussion of timber removals.

While total U.S. production of hardwood lumber has been roughly constant over the past three decades, there have apparently been substantial shifts in the mix of products consumed (Figure 2). Flooring consumption has declined dramatically, and tie consumption has apparently increased. Consumption in industrial markets declined from 1965 to 1975 but has grown from that point to the present. Pallet production, one component of the industrial market, is probably increasing but the data are especially poor for this end use of hardwood lumber. Hardwood lumber use in furniture and fixtures has remained comparatively constant over the period, but we suspect there has been some shift in the species and qualities of lumber which are used in this market. That pallet and tie consumption have increased, and flooring has decreased suggests that high quality end uses have declined in relative importance. However, the complex set of trends discussed above renders this conclusion tentative at best.

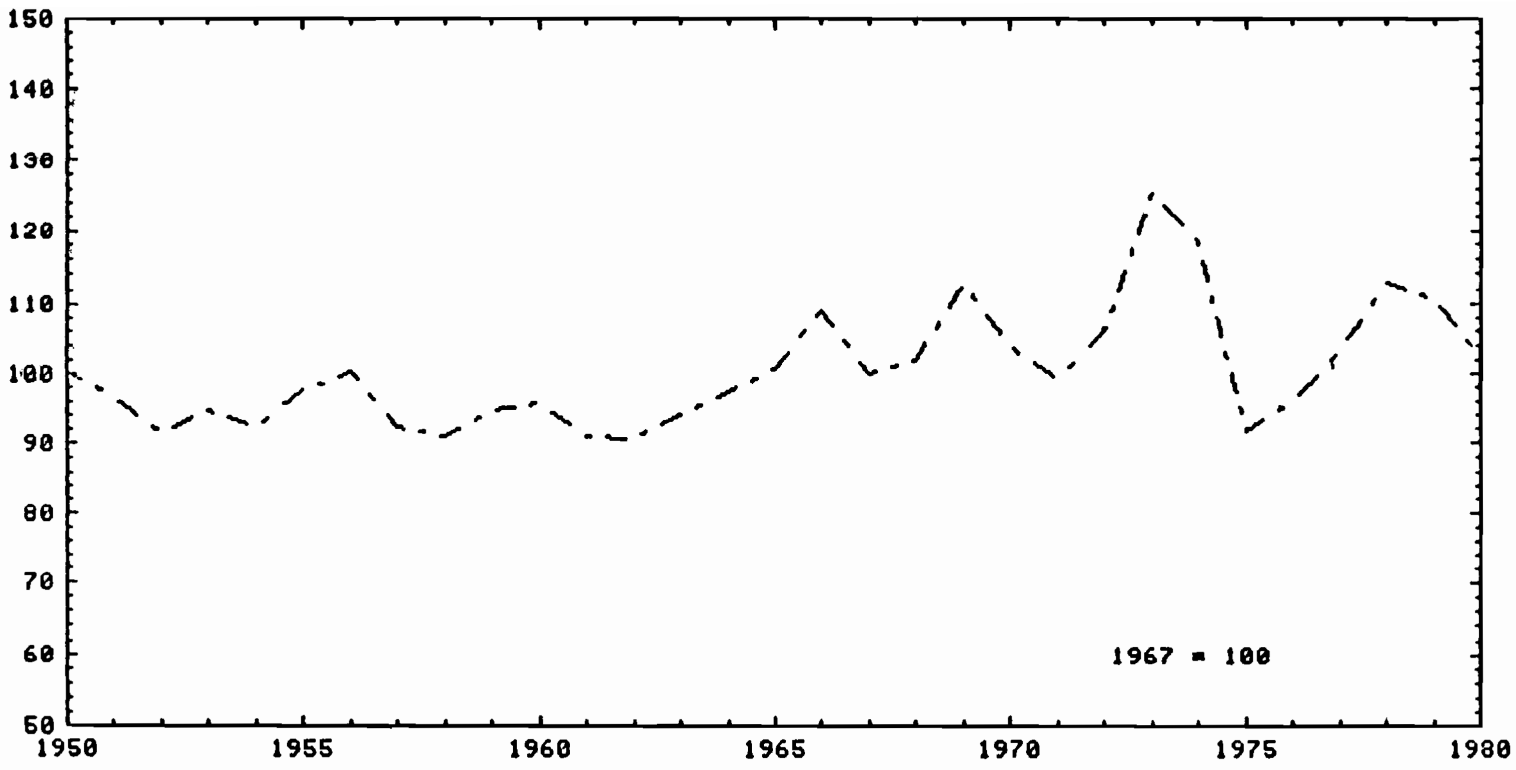

Figure 3 Real producer price index for hardwood lumber.

TABLE 3

Hardwood Inventory by Region and Ownership

	Public	Industry	Private Nonindustrial	TOTAL
North				
Inventory[a]	24.1	11.4	93.1	128.6
Removals[b]	205.2	190.7	1557.6	1953.5
South				
Inventory	10.8	16.4	77.7	104.9
Removals	124.1	357.8	1618.3	2100.1
West				
Inventory	10.4	4.1	7.2	21.7
Removals	24.7	47.2	57.2	129.3
TOTAL				
Inventory	45.3	31.9	178.0	255.2
Removals	354.0	595.7	3233.1	4182.9

[a]billion cubic feet

[b]million cubic feet

Source: USDA (1980)

TABLE 4

Cut/Inventory Ratio for Major Hardwood Regions

	1976		1970	
	Industry	Nonindustrial	Industry	Nonindustrial
NE	0.016	0.013	0.013	0.013
NC	0.019	0.021	0.019	0.023
SE	0.021	0.020	0.025	0.024
SC	0.022	0.022	0.036	0.039

Source: USDA (1980)

TABLE 5

Private Nonindustrial Commercial Forest Land in the United States, 1952-1977

	1952	1962	1970	1977	Change, 1952-1977 %/year
Farm	173.0	145.0	125.0	116.8	-1.6
Miscellaneous Private	122.8	159.4	165.4	166.4	+1.2

Source: USDA (1980)

Coincident with stable lumber output have been comparatively stable real lumber prices, as seen in Figure 3. The stability in output and price level raises potentially serious difficulties obtaining and using empirical estimates of supply and demand curves. There is no empirical basis for estimating output or price response to large changes in either lumber supply or demand. This limitation could lead to the incorrect inference that lumber supply is quite elastic, and may partially explain why previous studies have forecast relatively flat trends in hardwood lumber and stumpage prices.

2. Ownership of the Hardwood Resource

The hardwood timber resource is primarily a private, Eastern one. Table 3 shows that over 90% of the cut and inventory are in the East, and four-fifth's of the harvest in 1976 came from private sources.

One conventional measure of timber supply is the ratio of harvest to inventory. For softwoods, there are significant differences between industrial and nonindustrial ownerships, but Table 4 shows that the ratios are similar for hardwoods. A developing body of theory (Binkley, 1981a; Knapp, 1981) suggests that the supply behavior of the two kinds of private ownerships should differ in both the short and long run. That the cut-inventory ratios are similar indicates that both theoretical and empirical problems might arise in estimating stumpage supply equations.

Within the class of nonindustrial ownerships, there have been significant shifts in land use and ownership charactersistics. Table 5 shows, for example, the large decline in farm ownership of forest land and a complementary increase in "miscellaneous private" ownership. At the same time, the ownership size distribution is changing in a complicated way, and nonindustrial private holdings are probably decreasing in average size(Binkley, 1981b). All else equal, both trends will reduce timber supply from private nonindustrial forests, and will alter the apparent timber supply elasticity.

The considerations raise a number of important issues for modeling the hardwood sector. Time series estimates of supply models confound the effects of price changes and changes in ownership characteristics. Because the hardwood sector has been characterized by relatively stable prices and output, the empirical basis for estimating supply equations may be limited. Furthermore, long run stumpage supply equations are typically elastic for low price/output combinations and grow less elastic for higher price/output levels. Consequently it may not be realistic to project past and present experience which probably lies in the more elastic portion of the curve into higher price/output levels which might occur in a less elastic region.

3. Modeling Quality Differences

Log and lumber quality are commonly thought to be critical factors in the hardwood solid wood products sector. Returns to land management practices turn on grade improvement and valuation assumptions. Sawmill operators frequently claim their profitability depends primarily on their

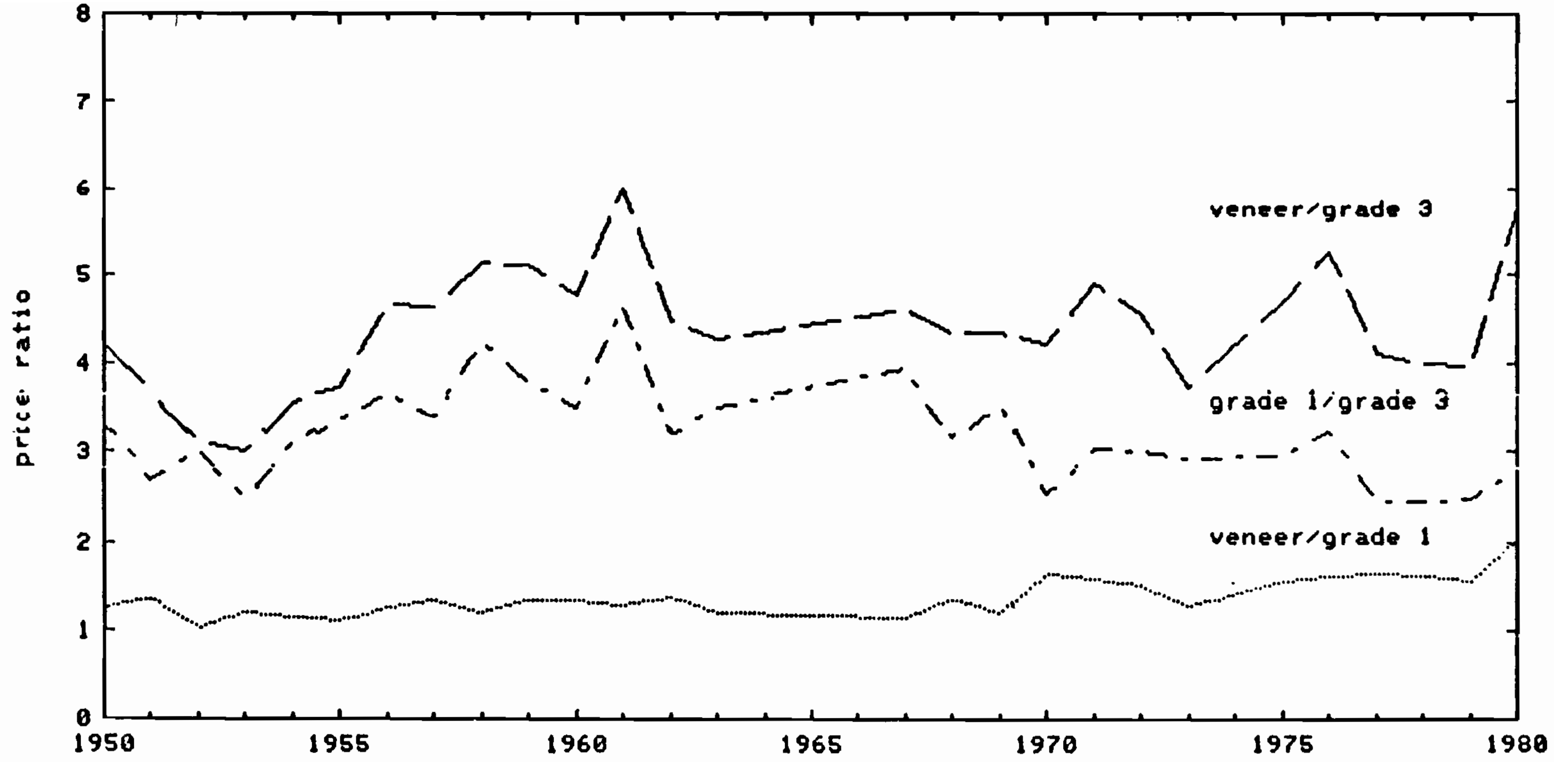

Figure 4 Relative log prices, Wisconsin Maple.

ability to produce high-quality lumber. We have seen that the major end uses of hardwood lumber are shifting in relative importance with an apparent decline in those uses requiring high-quality lumber (e.g. furniture) and an increase in those requiring low-quality lumber (e.g. pallets). The most recent Forest Service timber assessment summarized the situation:

> The demand-supply-price outlook for larger sized hardwood sawtimber of preferred species, such as select white and red oak, sweet gum, yellow birch, hard maple, walnut and black cherry is quite different from that for the smaller sized, lower quality material that composes most of the hardwood inventory. Removals of the higher quality sawtimber of preferred species have been close to or above net annual growth in recent decades, and continuing and large increases in stumpage prices have apparently reflected this situation. These trends are likely to continue. (p. 431)

This section examines some of the factors relevant to recognizing hardwood lumber and stumpage grade differences.

Ostermeier(1981) examined the historical change in the quality of the hardwood inventory, and concluded "although there has been some change in hardwood (inventory) by quality, the net change in the last two decades is almost zero" (p. 9). Data comparable to those presented in Table 6 were the basis for this conclusion. The 1977 hardwood inventory in the East contained about the same percentage of grade 1 and 2 trees as did the 1952 inventory and the 1977 inventory was substantially larger. Furthermore, in each of the subregions the inventory of hardwood sawtimber 17 inches dbh and larger (the minimum dbh to qualify as a grade 1 tree, assuming 16′ logs, 2"/8′ taper and a 1.5′ stump) grew over the past 25 years. However, in two of the subregions--the Northeast and the North Central-- the increase in inventory of this large sawtimber was less than that for the sawtimber inventory as a whole.

No records are available on harvest by tree or log grade. Consequently it is difficult to assess the trends in removals by quality classes. Trends in relative prices, however, give some insight into the path of the market equilibrium, and the importance of recognizing more than a single product grade. We examined grade differentials in both sawlog and lumber prices.

The only source reporting hardwood stumpage or log prices by grade is the Wisconsin Extension Service (Ulhrich, 1981, Tables 23 and 26). They report biannual prices of hard maple veneer logs, and grades 1, 2, and 3 and woodsrun sawlogs. To analyze trends in the relative prices of these products we constructed three ratios: veneer log price to grade 1 sawlog price, veneer log price to grade 3 sawlog price, and grade 1 sawlog price to grade 3 sawlog price. Figure 4 plots the history of these ratios. Veneer log prices are rising relative to grade 1 sawlog prices, but only modestly, if at all, with respect to grade 3 sawlog prices. More significantly, grade 1 sawlog prices are apparently falling with respect to grade 3 sawlog prices. Said another way, high-grade maple sawlogs are becoming relatively less scarce in Wisconsin.

This unexpected result lead us to examine trends in lumber prices. Ostermeier (1981) found that, at least during the 1970s, prices for lower

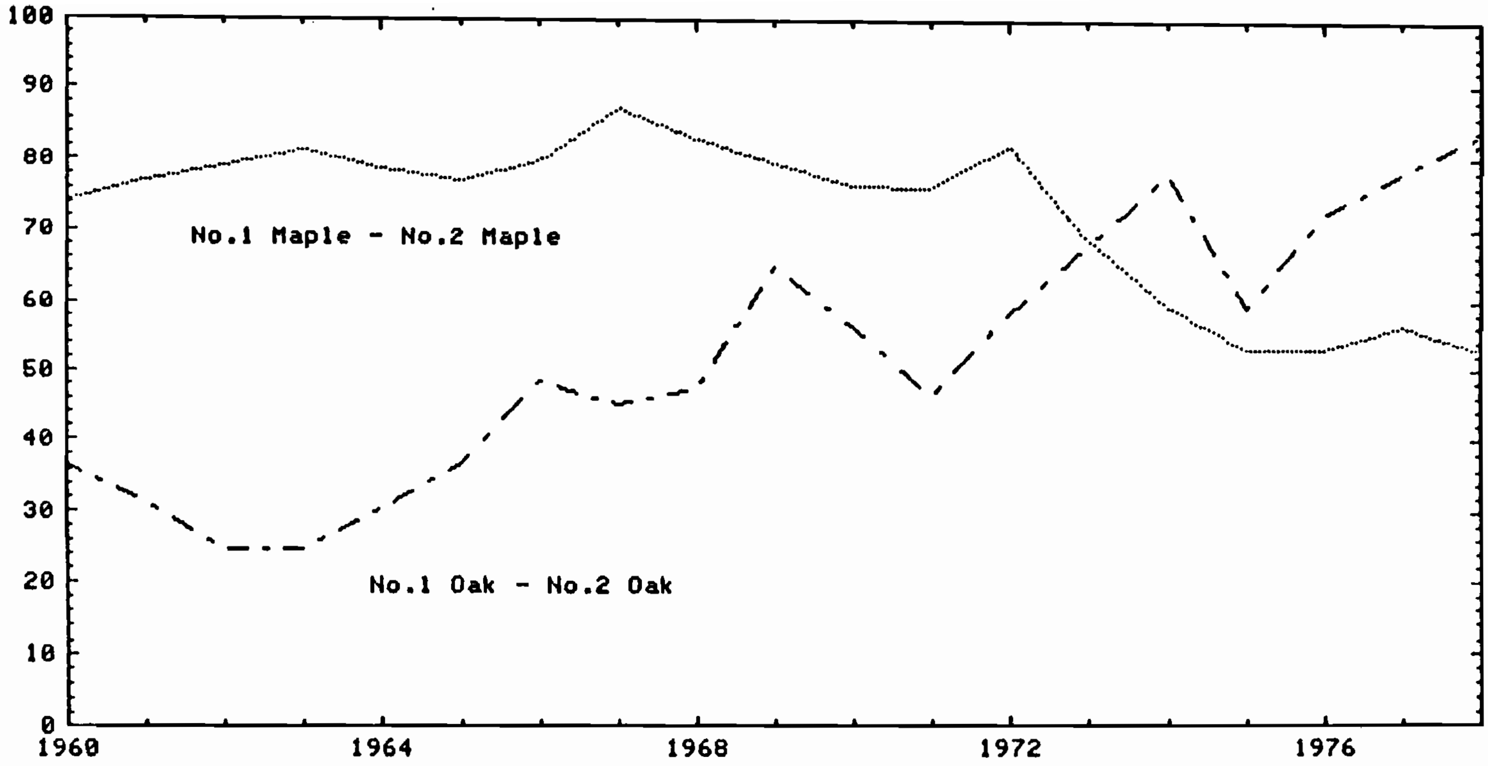

Figure 5 Lumber price differentials (1967$/mbf).

grades of oak and cherry rose more rapidly than did those for higher grades. Figure 5 shows the trends in the real price difference between grades 1 and 2 common lumber. The data for oak and maple are plotted, and show significantly different trends. The trends in maple lumber reflect the trends in sawlog prices, with the real price difference for higher grade material falling over time. In contrast, the price differential for higher quality oak lumber is rising. Hence the quality issue has a species as well as grade component.

This analysis, while limited and preliminary, suggests a complex set of markets and market adjustments related to the various grades of hardwood timber and lumber quality. Because relative prices of different grades are changing through time, it seems desirable to model at least two grades of hardwood timber, probably at least two grades of hardwood lumber and perhaps two or three species. Such an effort raises a number of data questions which will be discussed below, as well as several interesting modeling issues.

In the first place, high- and low-grade hardwood are joint products in both the stumpage and final product sectors. Consider first the final products sector. Mills can adjust grade recovery and total outputs to maximize profits, and logically the optimal mix of grades and volume will be determined by the relative prices of lumber and log grades. Grade recovery observed at any one time is a function of these price ratios and the sawing technology in place. For example, many sawmills now live saw for grade while sacrificing volume production or total recovery. Based on this practice, the Forest Service has conducted several grade recovery studies, and based on these studies the amount of various lumber grades from a sawlog of specified grade and dimensions can be estimated. Such a calculation obviously assumes that the estimated recovery rates remain optimal under different price relatives among sawlog grades and among lumber grades.

Finally, adjustments in recovery are one sided, in the sense that high-grade logs can be converted into low-grade lumber while the converse is not true. Thus increases in demand for high-grade lumber will in general lead to increases in low-grade lumber production, while increases in demand for low-grade lumber may not affect the total production of high-grade lumber. Some method for modeling the optimal or historical lumber grade recovery process is clearly necessary for modeling the converting sector.

Concerning the stumpage sector, high- and low-grade log production are joint products in both the short and long run. In the short run, supply is the amount of timber which is sold from the existing inventory. The propensity to sell timber is in part related to the total returns from the sale. Increases in the price of either high- or low-grade stumpage will affect both the total stumpage supply as well as the mix of products. In the long term, prescriptions for the production of high-grade stumpage generally involve some sort of thinning regime, which will produce some lower grade material. Thus higher prices for low-grade material could make the production of high-grade stumpage more economically attractive, and would be expected to increase the supply of high-grade material.

4. Timber Removals

Timber removals lie at the heart of the link between the stumpage and converting sectors of the hardwood model. Final product demands are translated into timber demand using recovery rates: the cubic feet of log required to produce a specified amount of final product (ideally recovery rates would themselves be endogenously determined.) Total demand on the timber inventory equals the sum of these demands plus removals for pulpwood, fuelwood and logging residues. Given these removals and assumed timber growth rates, the inventory can be projected forward one period and the process iterated.

Several questions arise out of this process: What are the appropriate recovery factors for translating product output into timber demand? How should timber demand be allocated between growing stock and nongrowing stock sources? How should other removals from growing stock be included in the model? How should total removals be allocated among ownerships and tree diameter classes? This section addresses several of these concerns.

Lumber Recovery Rates

Recovery rates for lumber are estimated as the ratio of hardwood used by sawmills to the amount of lumber produced. Lumber production data are available from the U.S. Census, but are subject to the limitations discussed above. Data on the quantity of logs used by sawmills are developed by the Forest Service in conjunction with their periodic resources evaluations in each state. Such data are also published on a regional basis with each of the periodic national timber assessments. Both state and regional estimates of hardwood lumber recovery are presented below, but the results are far from conclusive. These estimates exhibit wide variation across regions and over time. Due to the large errors in sampling and measurement, apparent trends in the industry must be interpreted cautiously.

Table 7 shows all of the lumber recovery estimates which are possible on a individual state basis (none of the southern state reports separate hardwood and softwood log receipts). For years in which these data were available, hardwood log receipts at sawmills were compared with hardwood lumber production by state. Lumber recovery estimates ranged from a high of 306 cf/mbf to a low of 158 cf/mbf. In every case, the data indicate that lumber recovery has declined from the previous survey.

Recovery rates can also be estimated using data on regional hardwood sawlog output in conjunction with regional hardwood lumber production. The advantage of this approach is that it relies on more accurate estimates of hardwood lumber production (individual state data are subject to large sampling errors). However, U.S. Forest Service figures on sawlog output are estimates of harvest and not receipts and we must therefore assume net log exports in a region are nil. Table 8 shows the results of the calculation. The trend in declining recovery since 1962 is seen in all regions.

Several secondary sources give estimates of hardwood lumber recovery rates. A recent study of hardwood log grades and lumber grade yields

TABLE 6

Grade Distribution of Hardwood Inventory, 1952-1977

	1952	1962	1970	1977
Sawtimber Inventory in trees > 17"dbh(Bbf)[a]				
NE	32.40	31.90	33.23	36.33
NC	41.50	42.38	44.35	47.08
SE	42.38	43.61	49.82	55.95
SC	44.81	43.44	43.59	52.25
% Sawtimber Inventory by Grade[b]				
Grade 1	14.2	10.0	-	13.8
Grade 2	19.0	18.0	-	20.3

Source: [a] USDA (1980)

[b] Ostermeier (1981), East only

TABLE 7

Hardwood Lumber Recovery Rates for Selected States (cf/mfbm)

	PA	WV	OH	MI	WI	KY	Single Estimates
1965		172					
1966							
1967					170		
1968							
1969	158			166		165	
1970							
1971							CT-199 IN-284
1972				173			NH-209
1973			281		179		MN-166
1974		192				173	
1975							
1976	202			198			
1977							
1978			306				
Rate of increase, cf/mfbm/yr	4.0	1.3	1.8	2.7	0.9	1.0	

Source: Based on hardwood log receipt data published periodically by the Forest Service for individual States and on hardwood lumber production data published by the Bureau of Census.

TABLE 8

Hardwood Lumber Recovery Rates for Major Producing Regions (cf/mfbm)

	1962	1970	1976	Rate of Increase, 1962-1976, cf/mfbm/yr
Northeast	155	205	197	1.9
North Central	195	193	227	1.2
Southeast	175	173	203	1.1
South Central	151	173	231	3.8

Sources: Regional hardwood sawlog output figures are derived from Forest Service assessments in 1962, 1970, and 1976.

Regional hardwood lumber production data are from the Bureau of Census.

showed that log requirements to produce 1000 board feet of lumber consistently ranged from 160 to 180 cubic feet for oaks, maples and gum (Hanks et al, 1980). Variations were due to factors such as species, log grade, and log diameter. Lange (1980) estimated recovery to be 161 cf/mbf irrespective of region or year.

Finally, the Forest Service estimated industrial roundwood consumption from product outputs data (Ulrich, 1981). Their implicit assumption was that recovery was stable at 153 cf/mbf during the 1950s and 1960s. A reevaluation of recovery rates in 1976 found the weighted average in the U.S. to be 166 cf/mbf. It is uncertain whether this change is indicative of poorer conversion efficiency or simply the result of measurement error.

The large differences in recovery rates between regions, and the decline in recovery rates over time are surprising. The downward decline in recovery rates stands in stark contrast with the experience in the softwood industry. Changes in final products--from dimension to boards, for example-- or shifts in the log mix may be responsible. A second hypothesis is that investment in new capacity and upgrading of existing capital may have been inadequate to improve conversion efficiency; the hardwood lumber industry has not seen the growth in consumer demand that has characterized the softwood industry during the 1970s. Clearly, improving existing knowledge of hardwood log yields would improve the capability for estimating hardwood stumpage models.

<u>Growing Stock vs. Non-growing Stock Removals</u>

A model which projects timber prices and inventory must explicitly consider the role of non-growing stock sources in meeting timber demand. Non-growing stock sources include: rough and rotten trees, salvable dead trees, trees less than 5.0" dbh, topwood and limbs from commercial forests, and any material from nonforest land. Non-growing stock supplies reduce the drain on actual growing stock inventories implied by any level of product output. The magnitude of this problem is depicted in Table 9. With the expected growth in pulpwood and fuelwood consumption, the problem is likely to become more serious over the forecast period.

<u>Other Growing Stock Removals</u>

Two important components of total timber removals that are <u>not</u> captured by measuring the derived demand from products are logging residues and "other removals." The latter is a catch-all category that includes cultural operations (e.g. timber stand improvements), land clearing, and changes in land use. Table 10 shows that these removals are significant, equalling almost one-third the total in 1976. By contrast, softwood removals for a similar purpose constituted only 11.9% in 1976. Any successful model of the hardwood industry must include both since they constitute a major drain on inventory.

5. <u>Conclusions</u>

Hardwoods constitute a major forest resource in the United States, yet our understanding of the sector--key products, production use, capacity

TABLE 9

Percentage of Product Demand for Roundwood Supplied by Non-growing Stock Sources, 1976

Northeast	9.0%
North Central	21.4%
Southeast	13.9%
South Central	10.5%
U.S. Total	14.0%

Source: USDA (1980)

TABLE 10

Growing Stock Removals not Accounted for by Product Demands, 1976

Northeast	32.6%
North Central	38.0%
Southeast	37.0%
South Central	21.8%
U.S. Total	32.2%

Source: USDA (1980)

trends, supply, within sector product substitution, demand, price and inventory development--does not match its complexity. In sum, we see six major issues in improving our hardwood assessment capability:

i. The data on product output and prices are limited and of questionable quality. The total lumber production data contain apparent abberations, and large sampling errors even at the regional level. Data on major end uses--pallets and furniture, for example--are sparse. Producer price indices do not reflect enough products to characterize adequately the sector. National forest sales represent a small fraction of the total amount of hardwood stumpage sold, so price series constructed from this source may not adequately represent hardwood markets in any region. Our ability to allocate removals to ownership, species and grade classes on the basis of empirical evidence is quite limited.

ii. Extant data indicate comparatively little variation in price or output for hardwood lumber over the past three decades. Consequently there is only limited empirical basis for estimating product supply or demand relations. Further, the past may lead us to overstate the actual hardwood lumber supply elasticity. The problem may be more troublesome in the stumpage sector as we move from an era of hardwood abundance to one of greater utilization. Long run stumpage supply curves are generally thought to be elastic for low levels of output converging to an inelastic asymptote (or even bend backwards) at high levels of output.

iii. Lumber and log quality differences seem to be an important consideration in modeling the hardwood sector, but in lumber markets different species and grades apparently interact in a complex way. Furthermore, high- and low-grade materials are joint products in both lumber and stumpage sectors. Changes in relative prices between product grades should provide some leverage in estimating the joint production function. Fuelwood and pulpwood complicate modeling hardwood grade because these products frequently compete for low-grade hardwood sawlogs.

iv. Nontimber outputs from hardwood forests are likely to play a larger role in hardwood timber supply as real incomes rise, as the shift from farm to nonfarm ownership of private forest land continues, and as ownerships decline in size. All else equal private stumpage supply will probably shift in, and the shape of the supply curve may change as well. Capturing these effects in a hardwood market model will require an understanding of forest land use trends.

v. Land use shifts also affect the hardwood supply through "other removals", or removals from growing stock which are not accounted for by product demands. For hardwoods these equal about one-third of all removals, and are therefore critical to modeling inventory development. Because inventory levels and character are likely to be significant determinants of stumpage supply, some satisfactory model for these "other removals" must be developed.

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USE OF SYSTEM DYNAMICS APPROACHES TO REGIONAL FOREST SECTOR MODELS

by

Vernon L. Robinson and Willard R. Fey

The Forest and Rangeland Renewable Resources Planning Act of 1974 (8) and The National Forest Management Act of 1976 (9) prescribe how land and resource management planning is to be conducted on National Forest System land. One of the guiding principles underlying these acts is the recognition that the National Forests are ecosystems whose management requires an awareness of the interrelationships among plants, animals, soil, water, air and other environmental factors within such ecosystems. Therefore, in the development and maintenance of land management plans, a systematic interdisciplinary approach is required to achieve integrated consideration of the physical, biological, economic, and other aspects of the National Forest System. Specifically, a team representing several disciplines is to be used at each level of planning to ensure coordinated planning which addresses outdoor recreation, range, timber, watershed, wildlife and fish, and wilderness opportunities. Clearly, an integrated ecosystem analysis and a human intervention and management analysis is essential to meet the requirements of these acts. The research described below is specifically designed to provide a vehicle for accomplishing such an analysis.

DEFINITION OF SYSTEM DYNAMICS

System Dynamics (SD) is a method of modeling the complex interactions that characterize our biological, engineering, managerial, organizational, and social systems. Its distinguishing feature is the application of feedback control principles to model problems. A feedback system exists whenever the environment leads to a decision that results in an action which affects the environment and thereby influences future decisions (3). Feedback control is fundamental to all life and human endeavor. For example, a thermostat receives temperature information and decides to start the furnace; this raises the temperature, and the furnace is shut off. A closing of the loop occurs and a delay intervenes between the initial action and the fed back results. Closed loops and time delays are characteristic of all feedback processes.

The loops do not function separately, but rather are coupled together to form complex feedback systems that are whole interacting entities. Change in one system part eventually has an impact everywhere in the system. The continuing operation through time of these loops creates the performance time patterns of the system's variables. The study of feedback systems deals with the way information is used for the purpose of control. It helps us to understand how

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the amount of corrective action and the time delays in interconnected components can lead to system behavior. Thus system dynamics is based on the philosophy that the behavior of a system is principally caused by the system's structure. The structure includes not only the physical aspects of the system but, more importantly, the "policies" that dominate decision making within the system.

A second aspect of the SD philosophy is the concept that systems are viewed most effectively in terms of their underlying flows of people, money, materials, information, etc. A meaningful framework then results from tracing the cause-and-effect chains through the relevant flow paths of the system. A causal loop diagram is typically employed as the first step in modeling. These diagrams show the major cause-and-effect links between the system variables; indicating the direction of the linkage, and denoting the major feedback loops and their polarity. A positive feedback loop has very predictable behavior in response to a change induced in any of its variables. The loop can only act to reinforce or accelerate that initial change. A negative feedback loop on the other hand acts to counter the direction of initial change in any of its variables.

From this perspective, all dynamic systems can be represented in terms of level and rate variables with auxiliary variables used to represent goals and other concepts that affect the rates. A level is an accumulation or an integration over time of flows or changes that come into and out of the level. For example, forest inventories grow or diminish over time depending upon the relative growth and harvest of the forest. A rate variable on the other hand is a flow or a decision that controls a flow into or from an accumulation. Forest system relationships can be translated into level, rate, and auxiliary equations that can be simulated by computer using a specially designed compiler program called DYNAMO (7).

ECOLOGICAL SYSTEMS AS FEEDBACK PROCESSES

Ecology is the study of organisms in relation to their environment (6). A community is an aggregation of living organisms having mutual relationships among themselves and their environment. Forest ecology, therefore, is concerned with the forest as a biological community with the interrelationships between the various trees and other organisms comprising the community and between these organisms and the physical environment in which they exist. The forest community and its habitat together comprise an ecological system, or ecosystem, in which the constituent organisms and their environments interact in a complex energy cycle.

All organisms within the ecosystem depend upon the utilization of an external source of energy, solar radiation. A portion of this energy is used by plants to manufacture food from inorganic substances by the process of photosynthesis (5). Although some of the resulting potential energy is released through respiration, most of it, in the early stages of growth, is transformed into organic substances which form the structure of the plant. Over time this biomass accumulates with the result that a greater amount of the food energy produced goes into the maintenance of the plant and less is available for the production of additional biomass. Typically, the biomass increases slowly at first, then more rapidly but it slows down gradually again as the plant matures. Thus, in a mature ecosystem, the energy fixed tends to be balanced by the energy lost through respiration. The growth of a great variety of populations--representing microorganisms, plants and animals--

have been shown to follow this sigmoid pattern. For example, in Figure 1 the general pattern of a 100-day autotrophic succession in a microcosm is compared with a 100-year forest succession (6). While the numerical magnitudes of the forest variables are considerably larger than those of the laboratory microcosm, there is a remarkable similarity in their modes of behavior over time.

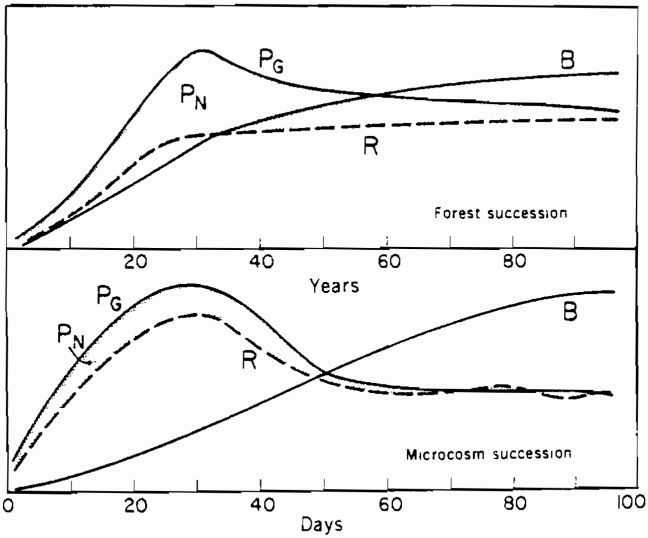

Figure 1. Comparison of Ecosystem Development in a Forest and a Laboratory Microcosm. Pg, Gross Production; P_n, Net Production; R, Total Community Respiration; B, Total Biomass (From Odum, 1971.)

The accumulated biomass provides a source of potential energy for animals. These consumers oxidize a considerable portion of the consumed material to release kinetic energy for body maintenance and transform the remainder into body structure. Eventually, all organisms die and bacteria and fungi dissipate the potential energy of the organic debris, transforming it into inorganic elements. From this inorganic state the plants may again use the dissolved nutrients in photosynthesis to manufacture food, thus completing the energy cycle. This cycle is known to have negative polarity, returning the system to a state of trophic equilibrium after an exogenous perturbation (1,5).

The cycling of mineral nutrients from the soil to the vegetation and back again is basic to all life. Therefore, it provides a useful starting point for modeling the interrelationships that exist in a forest ecosystem. In such a system energy, primary production, biomass, dead organic matter, and inorganic nutrients are accumulated as described above. These accumulations are determined by the material flows around the energy cycle and by the time delays that exist between these fundamental ecological variables.

The coupling of the positive and negative feedback loops will produce a time history of forest biomass accumulation which is consistent with that shown in Figure 1. In order to construct a testable model,[1/] this process must be articulated in terms of quantifiable interloop and intraloop relationships representing other variables of interest that exist within the forest ecosystem. The purpose here is merely to demonstrate that the balance of nature means that ecological systems are feedback processes. Hence, system dynamics is an appropriate tool for studying the complex interrelationships that exist among the trees, shrubs, herbs, bacteria, fungi, protozoa, invertebrates, vertebrates, oxygen, carbon dioxide, water, minerals, and dead organic matter which in their totality constitute a forest. The modeling of human intervention upon these biological processes is the subject of the next section.

HUMAN INTERVENTIONS IN FOREST ECOSYSTEMS

There are many aspects of the natural forest ecosystem that are beneficial to individual humans and human society. Therefore, one aspect of human intervention in the forest is use of the environment, land, and biological products of the forest. The forest environment provides recreation and wilderness experiences, the land contributes water and minerals, and the living forest produces timber, forage for domesticated animals, and wildlife and fish for hunting and fishing.

Since there is so much of value in the forest, a natural desire arises to increase, if not optimize, the forest's capacity to generate these benefits. A second type of intervention occurs when humans attempt to control the type and rate of growth of forest products. This can be done through such actions as seeding, fertilizing, selective cutting, and prescribed burning. Construction is often initiated to facilitate growth, harvest, or utilization. Roads, fences, water sources for grazing animals, and recreation and mining facilities are examples of this kind of intervention.

The former kinds of intervention are undertaken intentionally by the owners or managers of the forest to protect, develop, or use the forest's benefits. Another type of intervention involves unintentional impacts on the forest. Since there are so many people and so much mobility and industrial activity, even remote forest areas feel the impact of human action. Air, water, and solid waste pollution are extensive. Acid rain is becoming a major problem. Unauthorized timber cutting, grazing, hunting, and fishing are common. Intentional weather intervention (e.g., cloud seeding) for agricultural and other purposes often influences forest rainfall. Unintentional weather influences such as increasing carbon dioxide concentration in the atmosphere from fossil fuel use and ozone destruction in the upper atmosphere influence temperature, rain frequency and volume, and solar radiation availability, intensity, and wave length composition.

Despite the growing importance of these latter unintentional interventions, this paper focuses on the intentional interventions by forest managers. There are several characteristics of these impacts that are important. The first consideration is the balance required between protection or development and use. Too much

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[1/] A complete dynamic hypothesis of ecosystem succession can be found in Gutierrez and Fey (4). While this hypotheses was developed to represent a grassland ecosystem, it has general applicability to the process of secondary succession.

use destroys the forests' ability to reproduce itself. Too little use provides inadequate benefits to the users. "Appropriate" use simulaneously provides significant benefits while enhancing forest productivity and vigor.

The second consideration is the synergy or conflict among the uses. Usually a utilization action such as cutting an area for timber has benefits and detriments relative to other uses. For example after cutting, an area frequently becomes available for grazing for a period of time after new trees are established and until they are large and dense enough to interfere with grazing. Temporary detriments arise as certain creatures' habitats are destroyed along with some of the scenic beauty of the area. These tradeoffs become important considerations in forest management decisions.

A third consideration is the response time horizon. An action may be beneficial in the short run for some purpose, but detrimental in the long run for that same purpose or others and vice versa. Mining an area may provide significant immediate revenues, but may contaminate the land in such a way that reforestation cannot take place for many years. Burning may destroy biomass in the short run, but increase plant productivity and habitats of desirable creatures in the long run.

The interventions by forest owners usually require continuing actions, observation,and evaluation to ensure that the desired results occur and persist. This requires a continuing organization and management with authority and responsibility to determine and carry out the required tasks. The United States Forest Service is an obvious example of a continuing organization engaged in forest management necessitated by the need to continuously balance use and protection, control coordination and tradeoffs between uses, and reasonably balance short and long range benefits and detriments.

Financial considerations and constraints arise as soon as a continuing management activity is supported. Furthermore, the balancing of protection and use, the control of multiple uses,and the balance of short and long range considerations all contribute to the occasional need to provide costly intervention services and activities before benefits are realized. If money is required, a source must be found and control must be exercised over the utilization of funds. The consequence of this reality is that the forest biology, the decision structures of the associated human organizations, and the financial aspects of forest benefits and capital and operating costs of the organizations all become interrelated in the short and long run to form a single entity--the forest management system. The biological, human,and financial aspects of this system are related through coupled feedback loops that operate continuously through time to create the patterns of change of the system's variables. A simplified example of some of these interrelationships is illustrated in the causal loop diagram of Figure 2.

The natural forest ecosystem elements are shown at the top of the figure. These include the forest biomass, the production and mortality flows of the biomass and the nutrient pool that closes the cycle as described above. Below are shown some of the timber use variables. These include timber product inventory, consumption, consumption desired, and price; and the human population and economic system vigor that originate the demand. Like the forest ecosystem variables, the timber product consumption variables influence each other through closed loop relationships. For example, an increase in desired timber product consumption will increase timber product consumption. This will decrease timber inventory which after a time delay will stimulate an increase in timber product prices. Increased prices will reduce desired consumption and thereby close a negative loop of causal influences.

The human utilization system and the natural ecosystem are coupled through the forest harvest rate. This intervention is controlled by the relative harvesting desires of the forest owners and the timber users. The timber users' desire to harvest is influenced in part by the current availability of timber, timber product prices, and expected timber product demand. Forest owners' desire to sell timber is partially influenced by the amount of standing timber (biomass), expected timber growth rates, and expected timber demand. Timber price, an important consideration in both party's desires, has been omitted to simplify the diagram. Obviously, it and other influencial variables would be included in a more complete representation.

The purpose of Figure 2 is not to completely describe the forest management system, but rather to illustrate the closed loop nature of the couplings between the natural ecosystem, human consumption (intervention) and financial considerations (as reflected here in the timber product price). Other closed loop interventions occur when growth rate, nutrient pool and mortality rate are influenced by decisions to seed, fertilize, and burn. These activities arise when a need for them is perceived and money is made available in budgets to carry them out. The perceived need is established by observations of the biomass, growth, and mortality conditions in the forest and expected timber demand that are then related to the multiple use goals established by forest owners or the Congress. Budgets reflect the needs as legislators understand them and the consequences of not meeting them. The functioning of these feedback relationships through time creates the time histories of the variables. Increase or decline, oscillation or stagnation result from the way the loops are organized and coupled together. The SD methodology was created to quantitatively analyze such situations.

SYSTEM DYNAMICS ANALYSIS OF FOREST MANAGEMENT SYSTEMS

SD provides for the analysis and synthesis of dynamic feedback systems of all types. This is accomplished by carrying out certain activities in a prescribed logical sequence (2). The sequence begins with the clarification of the system's objectives and time history performance. Then the functional operation of the system is carefully observed and measured. The understanding of performance and operation obtained from the preceding investigations serves as a basis for developing a written dynamic hypothesis which identifies the feedback loops that are perceived by the analyst to create the major performance characteristics. Quantitative modeling of the relationships that compose these loops is performed to provide a basis for testing the hypothesis. The resulting model (set of dynamic equations) when simulated under a variety of conditions can be used for many purposes. Proposed changes in the feedback structure of the model can be tested to determine their effect on system performance, which is often found to be counter-intuitive.

The model can be a vehicle for training or communicating with people relative to the way the system operates. Expected future performance patterns can be forecast. The model can be simulated before extensive data gathering to estimate the importance of different kinds of information. This later application can be particularly useful for forest modeling because the long forest life cycle delays the availability of some types of information.

The application of the SD method to forest management systems (FMS) is difficult because the biological/human/financial interactions are so complex, reliable data is so limited, and the long forest life cycle is not synchronized with the much shorter political and organizational budget and administrative control cycles. Nevertheless it can be done by following the sequence described above.

Since the FMS is composed of many interrelated, but organizationally distinct, entities (e.g., the Congress; the Forest Service, and other federal agencies; private forest owners; industrial forest owners; timber product producers; state and local governments; and private citizens and organizations which function as timber product users, forest facility users, environmentalists, voters, etc.) there is no single objective for forest management or consensus on priorities for the multiple uses in the short and long run. The resulting conflicts, compromises, and competition among the groups are important determinants of system performance and must be included in the hypothesis and model despite the difficulties in determining their nature. Biological data are limited in what has been measured and the length of the historical records. Government and private organization data is also limited in extent and duration. But enough is available to establish a general picture.

The dynamic hypothesis will have to capture the complex nature and couplings of the biological, human, and financial feedback loops that comprise the FMS. The diagram in Figure 2 represents a beginning that will require elaboration through the collaboration of many people who are knowledgeable in the various areas. If the hypothesis development work is well done, equation writing (modeling) should not be too difficult. However, the large size and complexity of the FMS suggest that substantial time and effort will be required. The level of model detail required will be determined by the ways that the model will be used.

All model uses require two types of analysis--validation and hypothesis testing. Validation is a procedure in which the performance and the structure of the model are compared empirically and theoretically to the real situation. The purpose is to determine whether the model is a sufficiently accurate representation of reality to be used in the ways required. Since the model omits the less important aspects of the system's structure, model performance is not expected to perfectly reproduce the known historical performance of the real system. But the major patterns must be regenerated "accurately enough." Statistical measures are used when possible to determine the degree of accuracy. Expert multidisciplinary judgment is used to evaluate adequacy.

Hypothesis testing involves a series of simulations designed to reveal any errors in the hypothesis relating to the creation of the performance patterns. Each simulation has a specific causal consequence to test and requires a pre-written statement of the performance expected to which the actual model performance is compared. All model uses require prior validation and hypothesis testing.

USES FOR SYSTEM DYNAMICS MODELS OF FOREST MANAGEMENT SYSTEMS

SD models are designed to serve the purposes for which they are constructed. The factors to be included, the level of aggregation, the types of evaluation variables, and the use of random variables (noise), exogenous variables, and data or analytic driving forces are all dictated by model purpose. There even may be several different models that are needed to answer different questions or generate different kinds of information. A model's validity can only be evaluated in the context of its purposes. Therefore, it is important to know the kinds of things SD models can do.

Loop Dominance Studies (Sensitivity)

SD models can be used to determine the relative contribution of different loops, policies, and/or parameters to the creation of important performance patterns. "Will Forest Service policies for permitted harvest volumes or budgets for forest maintenance and development have a greater influence on future standing timber volume growth?" is a sensitivity question that a SD model could answer. The influence of estimated parameters, such as average stand maturation time and designated habitat area required per wild turkey, on costs and growth rates also can be determined.

Data Value Studies

Policy, loop, and parameter sensitivity studies relate directly to the importance of measuring various relationships accurately. If a $\pm$ 20% change in a relationship has a small impact on model system performance, it is probably not necessary to spend a great deal to measure it to 5% accuracy. Most feedback systems are relatively insensitive even to fairly large changes (errors) in most parameters, but a few sensitive ones are usually present. It is extremely valuable to know which are critical and which are not.

Management Policy Laboratory

In most systems the management policies (the guidelines for how to make the required decisions) are not thoroughly understood. People have been using them for a while, perhaps many years, but they really do not understand their total impact on all aspects of system performance. The SD model can be used to test a policy's impact on any biological, organizational or financial variable in the model. The policy may be one currently in use, one proposed by the system managers, or one arising from a creative synthesis by the SD analyst. Therefore, the model can be used as a management laboratory to answer, "what would happen if . . ." questions. This is an inexpensive way to identify ineffective or detrimental policies before they are tried in the real system where mistakes can be very expensive.

Forecasting of Future Performance Patterns

SD models can be used to forecast future time patterns. This is done in a simulation that starts the model accumulations at values corresponding to a real historical time, simulates the period of history up to the present, and then continues the simulation into the (model) future. The patterns (trends and oscillations) created by the model are forecasts of the real system patterns. Future events usually cannot be accurately forecast in this way. An event is the value of a variable at a point in time. Therefore, a SD model could predict a growth trend in standing timber or an oscillation in budget, but the specific amount of standing timber at a particular time would not be as reliable as the pattern forecast.

Budget Request Justification

In a system with long response delays, such as a forest, a current decision can influence performance for many years. An SD model that considers biological, organizational, and financial variables in the long run can be used to demonstrate the total long-run impact of policies, particularly in budget areas. This could be of significant value for private timber companies or government agencies such as the Forest Service when considering budget formulation and when submitting budget requests for approval by boards of directors or The Congress.

Training

An SD model is a mathematical representation of a real system that has the same variables as the real system and operates the same way as does the real system. The model, unlike the real system, is accessible and manipulable. Therefore, the model can be used to acquaint or train Forest Service staff, state forest managers, private forest owners, timber company managers, legislators, financial institution managers, environmentalists, or the interested public. In particular, by changing model policies and parameters and observing the effects of these changes on behavior, people can be helped to better understand the dynamic forces at work in the real-world system. An SD model of a forest can be a useful tool in public involvement as required by the NFMA and in conflict resolution since the resulting simulation is one of the most effective means available for supplementing and correcting human intuition.

Planning

Frequently, the people in an organization who first develop and use SD models are planners. Anyone who must estimate the long and short run consequences of many interrelated decision alternatives in a complex, imperfectly understood response environment, and then must apply multiple, time dependent, politically sensitive evaluation criteria to the estimates has a very difficult task. The realism of SD models and their easy use through the DYNAMO Computer language can provide considerable help to forest system planners who face this type of situation daily.

CONCLUSION

Forest management systems are composed of many biological, human, and financial accumulations and relationships that are organized into feedback loops that control the operation of the system parts and determine the performance patterns through time of the system variables. The SD method has been developed to assist the understanding, modeling, planning, control, and improvement of systems of this kind. SD focuses more than other analysis methods on the whole system, information feedback control process that creates in a realistic way the dynamic performance patterns. Therefore, it seems appropriate to suggest SD's use as a tool to understand and improve forest management systems.

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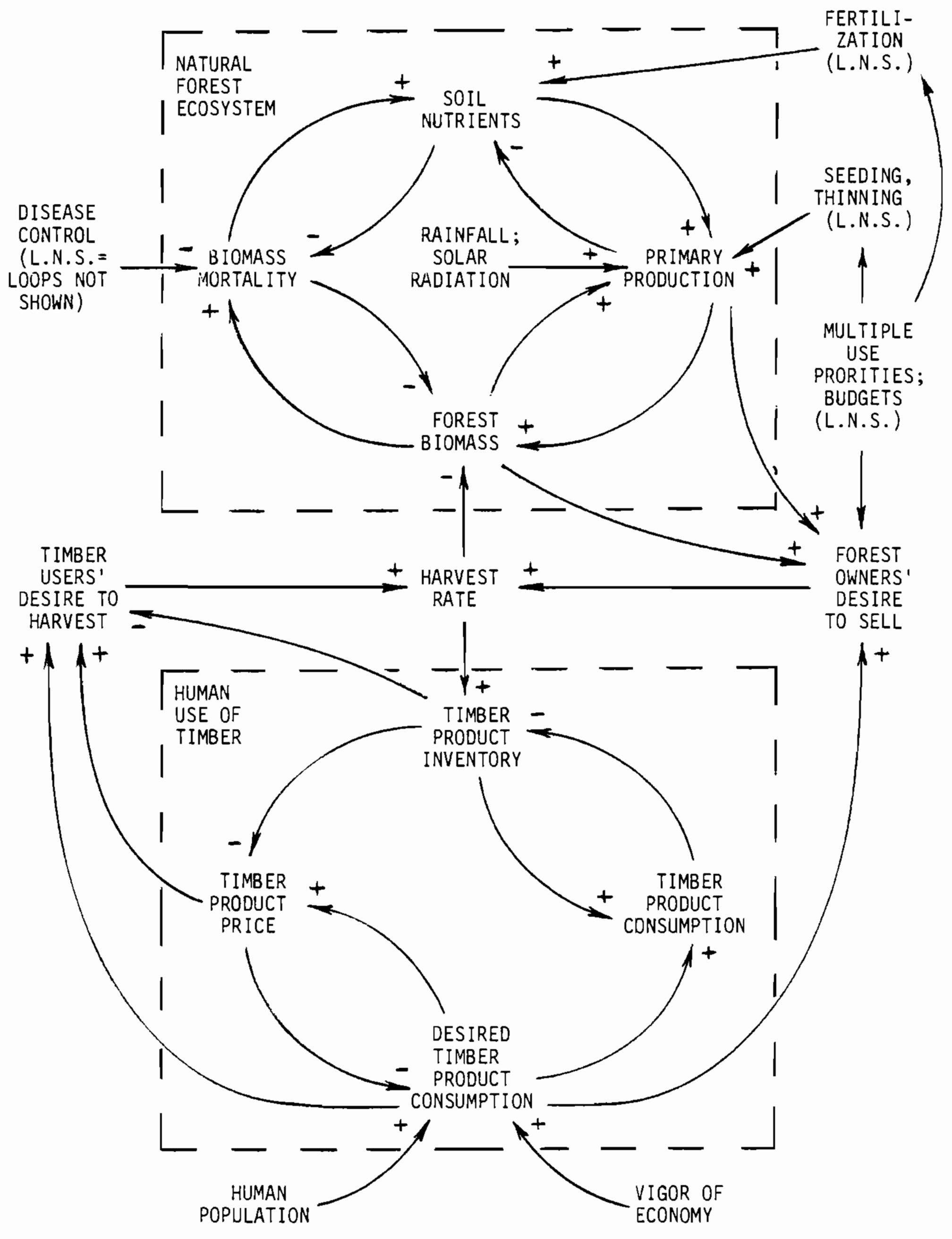

Figure 2. Partial Forest Management System Diagram Showing Ecological, Human and Financial Feedback Interactions

CONCEPTS OF HIERARCHY IN FOREST SECTOR MODELING

by Wolf D. Grossmann[1] and Eberhard F. Brunig[2]

Abstract--Hierarchical approaches in the building of forest sector models are more than just technical tricks to make modeling easier and more flexible. If done properly, the models within the hierarchy will in many respects be more adequate for their purpose: in their data, their internal structure, the problems that they address, in their output, and for their addressees.

INTRODUCTION

The term forest sector refers variously to more or less expansive systems, depending on the nature of the problems that are to be addressed. Accordingly, forest sector modeling can be concerned with "only" one forest-biosystem up to all biosystems within one nation or even on a global scale, including their human environment, which means including social, economic, ecological, land-use and other structures.

All these configurations of forest sectors are organized in a hierarchic manner (Brunig, 1971), like most complex systems, see Bertalanffy (1966) and Simon (1962). This hierarchical feature applies irrespective of their size and comprehensiveness. The arguments in favor of this hierarchical nature of such complex systems have been given, among others, by Bertalanffy (1967, he cites earlier references), Mesarovic et al. (1971), and Simon (1962). Simon gives some proofs, that systems can be built and maintained (or maintain themselves) far more easily if they are hierarchically organized. As large-scale models have often failed (Lee, 1973, Holcomb, 1976, Holling, 1978, Jeffers, 1976, 1978, 1979, 1980, 1981), it seems reasonable to devote different models of a forest sector modeling approach to different levels within the hierarchy of the forest sector under consideration and then split the task of modeling into subtasks.

This hierarchical approach to modeling is much more than just a device to circumvent difficulties inherrent in large-scale modeling. Models on different levels within the hierarchy differ in their permissible and reasonable size, internal characteristics, their data, functioning, objectives, outputs, adequate modeling techniques, problems to which they are devoted, and their addressees. Thus models have often failed due to level--inadequacy in technique, size, output, addressees--irrespective of their technical or scientific value. Large-scale models on a low level can be very successful, for example, the budworm model (Holling, 1978), while the results of such

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models have to be condensed and adapted to entirely different forms for use on high levels, see the slide show presented in Holling (1978).

Hierarchical modeling has been applied to regional planning (Vester, 1978, 1979, Vester and von Hesler, 1980), to city projects (Grossmann 1981a, 1982d) and natural and man-made ecosystems (Brunig et al., 1981a, 1981b), to renewable resources (Grossmann, 1981b), etc. Many ideas from Bossel (Bossel, 1977, 1978, Mueller-Reissmann and Bossel, 1979, Krause et al., 1980) have been very important in this work.

In Figure 1 one configuration of a hierarchy of models is shown. This description neglects details of the models, but focuses on the delimitations of the models and gives some reasons why this configuration seems advantageous. The central model and the forest sector model are operational on a computer, although in a preliminary version (Grossmann, 1982a). Several versions of the forest stand and stand structure model have been developed to maturity by Schneider (1980) and Schneider et al. (1981).

THE FOREST SECTOR MODEL IN THE HIERARCHY OF MODELS

The forest sector model in the hierarchy of Figure 1 describes the forest sector of a nation in the narrow sense on an aggregated basis: it contains the stock of forest resource, its growth, natural decay and harvest, the supply of forest products, the capital investment in the forest sector, patterns of forest ownership and other variables and many interconnections between these variables. The growth and stock of one kind or several kinds of forest resources are usually included in most forest sector models. Growth and stock both depend on the available land area, the quality of the soil, the density of the stock, the harvests, to name just a few variables, which are incorporated in the available models.

Growth normally behaves natural-law like and accordingly responds to the density of the forest crop, which in turn is influenced by growth, harvests, and mortality. Using feedback loops these biodynamics can be modeled quite well. The results in most cases are good approximations to reality. If, however, harvests (due to demand from the central model) exceed regrowth, then actions may be taken to increase regrowth, such as thinning, irrigation, or fertilizer application, planting of improved genotypes, planting new and more effective species, etc., depending on the particular circumstances such as climatic and soil conditions, availability of capital, availability and training of workforce, and technological know-how.

The most appropriate action to be taken and its probable outcome is only partially predictable because, for example, changes of technology are often unpredictable. Moreover, irregular events such as windthrow or stormbreak can occur on unusually large scales or unusual combinations of extremes of variables. In 1967 large areas of the pine plantations in northwestern Germany were devastated by windthrow. The unusual weather since 1977 has

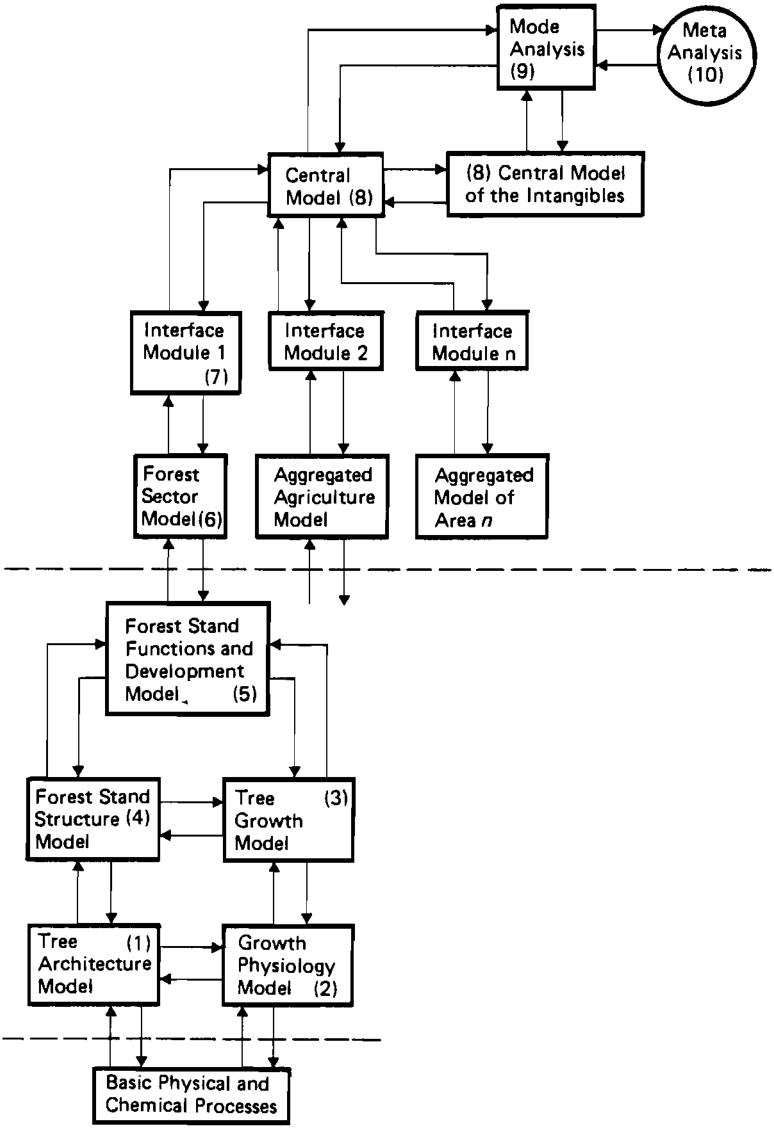
Mode Analysis (9)
Meta Analysis (10)
Central Model (8)
(8) Central Model of the Intangibles
Interface Module 1 (7)
Interface Module 2
Interface Module n
Forest Sector Model (6)
Aggregated Agriculture Model
Aggregated Model of Area n
Forest Stand Functions and Development Model (5)
Forest Stand Structure (4) Model
Tree (3) Growth Model
Tree (1) Architecture Model
Growth Physiology Model (2)
Basic Physical and Chemical Processes

Figure 1.

caused unexpected and unusually high losses in pine due to snowbreak. The high increase in energy costs revived the demand for fuelwood in Germany and elsewhere while rising wages of laborers and environmental restrictions on establishing sulfate pulp mills in Germany prevent young stands to be adequately thinned and tended, thus making the forests even more vulnerable.

The climatic events affected the "correctness" of the modeling results of most forest sector models at least for great parts of West Germany. Increased demand due to the substitution of oil by wood destroyed the correctness of demand figures for most countries. These figures partially determine the amount of harvest and depletion of stocks. The evidence of such events limits the usefulness of all forest sector models. A decision maker, who wants to base his plans on the results of such models, has to be aware of two factors:

(i) The unreliability of such models--he usually is, or is at least feeling unease about the models.

(ii) The degree to which forests in his area are prone to breakdown--he usually belittles any susceptibility to breakdowns.

Both the decision maker and the models on the more deterministic levels of the hierarchy (the forest sector and the central model) can get valuable information from additional models that address these problems of stability (or reliability or predictability). The term "viability" includes reliability, stability, predictability, resistance, reproductivity, and resiliance, etc., although in a complex and not obvious manner (Grossmann, 1982b). Thus "viability" seems to be an adequate name for this desired property of systems.

The meta-analysis (see Figure 1) is devoted to the problems of viability.

THE CENTRAL MODEL IN THE HIERARCHY OF MODELS

In the model version, which is already operational, the central model depicts the relationships between population, the economy, nonrenewable and renewable resources (for example, substitution), land-use, pollution, erosion, the food sector and human-ecological conditions. Out of this the land-area available for the forest resource, the demand for forest resource, the impact of pollution on the forest resource, etc., are computed, and given to the forest sector model.

Again, some relationships in this model are quite strictly determined (land used for infrastructure can seldom be used as well for forests). Some of these relationships are only partially determined: if the relative scarcity of a resource increases, substitution processes will start. The characteristics of that technological know-how, for example, which is available at the time of this scarcity, determine which substitution processes will be used.

Many relationships that will occur in the future are unpredictable: there are changes in vogues, in preferences, there are changes in the relative value of resources. In the substitution of resources, fashions are often important. In furniture there have been such waves of preference: first white painted furniture, then teak, then plastics, then pine, then oak, In the building of houses we had preferences for bricks, then for concrete, then for brick and wood. (All preferences are reported for West Germany.) The probability, possibility and impact of such basic processes of change are analysed in the mode-model (or mode-analysis). A direct analysis of these processes is impossible, but this indirect approach is sometimes very helpful.

THE META-ANALYSIS

The meta-analysis explores the viability of the forest sector and its environment as depicted in the central model. On this level of analysis, highly aggregated, naturally very imprecise terms are adequate. These variables are named meta-variables as they rely partially on the evaluation of results of lower-level models. An example of the application of the meta-analysis is given later, which uses the following two meta-variables:

(i) Structure of the system.

- -- Degree of hierarchical organization, which can be valuable in order to increase the viability of a system as reasoned by Simon (1962).
- -- Multifocal organization (term from Boyden, 1978). A system is more valuable if it is out of reasonably tight interconnected subsystems ("focal points"), which are only loosely connected to other subsystems. This result goes back to Ashby (reported in Vester, 1979). See also Ashby's later paper (Gardner and Ashby, 1970) on "connectivity and stability".

(ii) Variety within the system.

- -- Diversity coming from the number of species; or number of crafts, etc. (diversity in the small environments).
- -- Diversity due to number of biotopes or branches in the economy, etc. (diversity on a large scale). There have been many discussions about the relation between diversity and viability; see, for example, Brunig (1966, 1970, 1973, 1975, 1977).
- -- Genetic and other differences within each species (or craft, etc.).

Ashby (1960) states "only variety can destroy variety" (only variety within the system can overcome the variety of the environment of the system). The two meta-variables (structure of the system and variety) can be applied to New Zealand's present program of planting Radiata pine on large areas.

After Great Britain joined the European Common Market, New Zealand could no longer exports its agricultural products to Great Britain. As a consequence, many farms in New Zealand were no longer profitable and the land was no longer cultivated. Now on most of these farm areas, Radiata pine is planted (95% of all new plantations of trees). In New Zealand pinus radiata has a rotation time of 35 years. The new plantations are distributed in a leopard-spots manner over both of New Zealand's main islands (Figure 2).

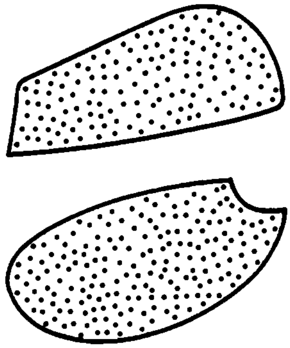

Figure 2.

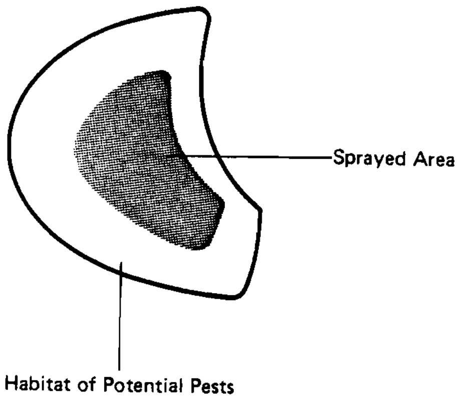

Figure 3.

Because of the low diversity, these plantations are very attractive for pests, as pests are specialists. Spraying with pesticides can help for some time, but often fails. Holling (1978) reports the temporary breakdown of cotton planting in California. A first spraying was successful in substantially reducing all seven pests of cotton, and production rose by 50%. But six new pests became as serious a problem as the original seven had been. The reason for the appearance of these new pests was the elimination of the parasites and predators that were killed by the insecticides. In the case of New Zealand, most probably pests living in the environment of pine plantations will accidentally be sprayed from time to time (see Figure 3). As this spraying will not systematically eliminate these pests, they will first adapt to the pesticides and then realize the ecological niche in their neighborhood, and consequently adapt to Radiata pine. In the case of California's cotton the seven original pests also adapted to all insecticides. Only integrated pest management succeeded in overcoming the problems posed by these pests.

Cotton can be planted anew each year. Once a species of pest has adapted to the pesticides and to pinus radiata in New Zealand it can destroy all the pine in its environment for at least 35 years and then will begin to jump from pine island to pine island. At present, New Zealand is exporting 50% of its wood. If all pinus radiata will grow as projected, in 2015 the wood supply will increase six fold, that is, New Zealand could increase its exports even more. But if a pest succeeds in destroying all pine plantations on both of New Zealand's islands, the nation will have to import wood. If the resistant pest is stopped by the sea and contained on one of New Zealand's two main islands, the export in 2015 will be roughly six times today's volume.

The forest sector model would project the growth of the pine up to the year 2015 as expected, resulting in the six fold increase in supply (twelve fold export) over today's volume. If the forest sector model is built especially well so that it contains a feedback structure describing growth, it would exhibit even such details as the somewhat more rapid growth if some trees are presumably harvested. But this degree of sophistication in the forest sector model may be irrelevant as in fact all outcomes, ranging from the necessity to import wood to a twelve fold increase of exporting capacity, are possible. This result of the meta-analysis contrasts sharply with the blue-eyed confident projections of the forest sector model.

The meta-variables can also be applied to make this system more resistant:

(1) The diversity of plantations can be increased.

(2) Zoning regulations can be prescribed, banning some species in some regions to prevent island jumping and banning some pesticides in other regions to have back-up pesticides; adopt techniques of preventive integrated pest management, etc. to make the structure of the system more viable (see Figure 4).

Application of this meta-approach, however, creates one problem. At present, the plantation of Radiata pine seems to be optimal. Increase of

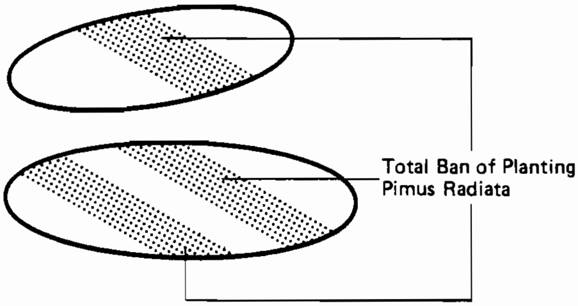

Figure 4.

diversity of plantations is costly for those farmers who are forced to plant species other than Radiata pine. Who pays them for their losses? These costs are a kind of insurance premium to prevent undesired breakdowns.

THE MODE ANALYSIS

The history of forests is a history of drastic basic changes. During the 18th century Germany abandoned the course of continued deforestation--only very few forests were left at that time--and switched to afforestation. Eventually the whole country fell in love with the forests. The German forest birds were enthusiastically declared to be "the best singers in the world", although no species of bird is specific to Germany. The forests played a central role in Germany's most famous ultra-romatic opera ("Der Freischutz" by Weber). In 1982 afforestation still continues, although at a slower pace; the forest areas have now exceeded 30% of the total land area.

In the 1870's Britain's Royal Navy planted oak forests to ensure continued supply for the building of war ships. Moreover, all oaks that were growing straight were eliminated, because bent oaks were most appropriate for ship-building. Now these oaks have matured. Although oak wood is very rare and very expensive, nobody can use bent oaks today.

In 1980 the French Telephone Office replaced the telephone books--paper is made out of wood--by telecommunication devices. More such substitutions of wood products by information processing devices certainly will appear. This again is a process of drastic basic change (from a material resource to an information resource), which can well destroy the validity of many models on the forest sector level and the central model level.

On the mode-level, tools such as the logistic development functions, Marchetti and Nakicenovic (1979), Marchetti (1981), see Figure 5; Thom's (1975) catastrophe theory (an application of Thom's cusp catastrophe to the budworm-spruce system in northeastern Canada is given by Jones, 1977), or Prigogine's results are appropriate and useful (Prigogine et al., 1977, and Allan and Sanglier, 1978, 1981). As a brain-twisting application of the logistic development function, think about the problem "why will the importance of electricity have drastically declined in 2030?" The mode-analysis, like this brain-twister, usually will not give valid forecasts. But it helps to get a better feeling for the validity and applicability of lower-level modeling results. As a further application of mode-analysis, think about the problems: which basic changes will happen in New Zealand and the international markets if

(i) all of New Zealands Radiata pine plantations are destoryed

(ii) circa 50% of New Zealands Radiata pine plantations are destroyed

(iii) New Zealand succeeds to attain a bumper harvest of Radiata pine.

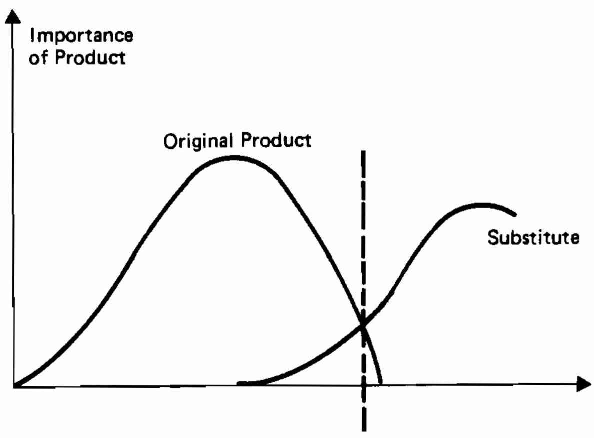

Figure 5.

LEVEL ADEQUACY

The addressee of the meta-analysis about the desirable increase in the diversity of New Zealands plantations of forests is not the individual farmer nor is it a local government. High-level models address high-level problems for high-level decision makers. Once regulations about desirable diversity and about zoning have been made on the highest level, intermediate to low-level models are adequate to address the problems of optimal mix of plantations or even about optimal planting and harvesting policies for the individual farmer. Huge lists of output may be necessary to assist in planting, thinning, and harvesting. These lists, however, are of no interest to the high-level decision maker. The data for low-level studies are very precise, abundant, readily available. Typical low-level problems are the real time process control in industrial plants or the control of physiological processes in living elements of biosystems. Intermediate level data are more subject to systematic errors (Majone and Quade, 1980) and more subject to influences from the outside. They are much more aggregated than low-level data: the workers on one plantation on the level of the topic models (Figure 1), are only a part of the work force in the forest sector model, this work force is only a part of the total work force on the level of the central model. In the meta-analysis, the work force of the central model contributes to the variable diversity of the system.

On the highest level, data are scarce, naturally imprecise (precise data are inadequate on this level), and subject to drastic changes by the environment of the system, as well as by internal changes of the system. The methods, which have to be applied on different levels of a system, differ accordingly. On low levels fast, precise, "brute-force" decision making methods are adequate, like real time process control, optimization, etc. On intermediate levels, feed-back models, averaging processes, etc., are adequate. On higher levels cautious evaluation of meta-criteria is helpful. These meta-criteria, however, are based partially on results from lower levels. Thus no method is obsolete; all are important, all have their place, no method is the best overall. Used together, these methods are supplementary and enhance each other's effectiveness.

CONCLUSION

The forest sectors in whatever configuration are complex hierarchical systems. Here systems analysis and modeling can be valuable tools. The modeling of the forest sectors becomes simpler and more adequate if for each level within these hierarchical systems individual models are built, which are internally organized in a way adequate to that level, which address adequate problems and produce level-adequate results directed to the level-adequate addressees.

Thus the concept of hierarchy in forest sector modeling is more than a device for better modeling. It is an approach that is aware of the characteristics of each level in the reality and that treats these levels according to their characteristics. This leads to better and more adequate models, which accordingly can be more successful in research and application.

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TOWARDS AN INTERDEPENDENT SYSTEM OF MODELS FOR AUSTRALIAN FOREST SECTOR ANALYSIS

David F. Batten[1]

November, 1981.

Abstract. In the search for a plausible system of models to analyse developments in the forest sector over space and time, current systems thinking suggests a hierarchical approach. If the development problem is successively disaggregated, we can coordinate economy-wide modeling at the international and national levels with forest sector analysis at the regional levels. This paper outlines such an interdependent system of models for the Australian forest sector. Submodels for forestry, the forest industry, and the market for forest products are proposed, and the salient features of some existing models are described. The resulting model structure may be adopted in Australia's contribution to the IIASA Forest Sector Study.

Keywords. forest sector analysis, economic models, hierarchical systems analysis, forestry, forest products, industrial development.

INTRODUCTION

In recent years, Australians have accumulated a modest amount of experience in modeling certain elements of our nation's forest sector. Apart from several multisectoral modeling exercises which have focussed on the interactions between various industries in the national and regional economies (including forest-related sectors), there have been model simulations of future levels of supply and demand for some exotic softwoods (Treadwell, 1979), and various models have been developed for plantation management by the Australian Forestry Council. Other studies of the future supply of, and demand for, forest products have also been completed.

Basically these investigations suggest that Australia will move from its current position of about 15% under-supply (met by imports) through a period of self sufficiency in the eighties. By 1990, an excess supply of exotic softwoods will occur due to extensive plantation activity in the sixties. As we enter the twenty-first century, Australia will have joined New Zealand as an active exporter of processed timber. The financial viability of the timber industry will then depend on export demands in the form of pulp and paper, particle boards, linings, joinery and other wood products,

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as well as Australia's own rate of growth and internal demand.

Meanwhile, rainforests have declined from 1% of the area of the continent two hundred years ago, to only 0.25% today. Factors responsible for this decline relate predominantly to population growth and economic development. Various land uses such as mining, agriculture, water catchments, recreation and conservation are competing for our native forests. Furthermore, some of the timbers from private forests are being used for inappropriate purposes, and many important species (such as huon pine, cypress pine, jarrah and kauri) will not be adequately regenerated unless proper forest management policies are introduced (Kimmins, 1973).

The resulting dilemma in Australia, as in many other countries, is that forests are quite versatile natural resources which can provide pleasure and leisure (for example, tourism, birdwatching, walking, orienteering, hunting, fishing) as well as forest-based raw materials. To achieve realistic and satisfactory insights into the performance of the entire forest sector, a holistic approach is needed. Within a comprehensive interdependent system of models, various conflicting interests, externalities and spillover effects can be recognized and assessed.

In this paper, such an interdependent system of models for the Australian forest sector will be outlined. We begin by summarizing pertinent features of Australia's forests, forest industries, and the market for forest products. The high degree of interdependency between various elements of the forest sector is illustrated. Then the forest sector model is described, consisting of five basic modules: forestry, wood market, forest industry, forest product market, and demand for forest products (Lönnstedt and Seppälä 1981). Finally, the relationship of the forest sector to other sectors of the regional, national and international economies is examined, resulting in a hierarchical system of models to analyse feasible development paths for the Australian forest sector over space and time.

AUSTRALIA'S FOREST SECTOR

The following brief summary of Australia's forest sector is divided into three sections: (i) forests, (ii) forest industries, and (iii) the market for forest products.

Forests

The most recent estimates of the size of Australia's forest resources are given in Table 1 (Australian Forestry Council, 1981). Eucalypts, which form the bulk of Australian forests, have been subdivided into three productivity classes (I, II and III), in decreasing order of productivity. Table 1 also contains comparable estimates for 1977 (French, personal communication).

Table 1: Australian Forest Areas
(thousands of hectares)

	1977	1980
Total land area	768,000	768,000
Woodlands	64,000	65,000
Native forest areas	43,400	40,884
Rainforest	1,900	1,884
Eucalypts I	3,100	2,688
Eucalypts II	14,100	13,635
Eucalypts III	12,400	11,778
Tropical Eucalypt and Paperbark	6,500	6,528
Cypress Pine	4,400	4,371
Plantation areas	668	766
Coniferous	618	718
Broadleaved	50	48

Sources: Australian Forestry Council (1981) and French (personal communication)

The declining area of native forests is clearly evident from this table. Eucalypts in the highest productivity class I have suffered a loss of 13% over the last three years. However, plantation areas of pinus radiata have increased by a similar proportion over the same period. Rainforests will play a decreasing role in commercial wood production during the eighties. From the figures in Table 1, it is clear that any innovative industry which can take advantage of the plethora of eucalypts would give Australia's forest industry international significance.

Forest industries

Estimates of the future availability of logs from Australian forests are given in Table 2 (Australian Forestry Council 1981). Sawlogs include logs for ply and veneer manufacture. Pulplogs include poles, posts and mining timbers. The assumptions upon which these estimates are based are as follows:

Table 2. Estimated Future Supply of Australian Logs
(thousands of cubic meters net)

FOREST	SPECIES	PRODUCT	1985	1990	2000	2010	2020
Native	Broadleaved	Sawlogs	4115	3762	3184	2980	2807
		Pulplogs	6284	6186	6208	6125	6128
	Coniferous	Sawlogs	359	338	336	380	380
		Pulplogs	-	1	1	1	1
Plantation	Broadleaved	Sawlogs	-	-	-	-	-
		Pulplogs	26	311	311	311	311
	Coniferous	Sawlogs	3019	4061	7471	10145	10606
		Pulplogs	3742	4602	5168	5442	5698
TOTAL	All forests	All logs	17545	19261	22679	25384	25931

Source: Australian Forestry Council (1981).

(i) that relative levels of costs and prices affecting harvesting and processing operations remain identical to those applying in 1979/80; and

(ii) that wood volumes available in the earlier forecast years will actually be utilized, with thinning and clearfalling operations occuring on schedule.

These two assumptions presuppose certain demand influences, including the continuation of current population growth trends and maintenance of the present market position of wood products vis a vis alternative products. Structural adjustments and substitution effects in the market for forest products may invalidate such assumptions, but more sophisticated model structures will be needed to generate alternative scenarios.

In keeping with trends in the forests themselves, the availability of logs from native forests is expected to decline substantially over the next twenty years. However, the dramatic increase in logs supplied by the coniferous plantation forests will more than offset this dwindling supply of broadleaved native varieties. The net result is an average increase in log supplies of about one percent per annum over the next forty years.

The market for forest products

The principal characteristic of the Australian forest sector is a high degree of interdependency between its own industries. Forestry and logging are linked directly or indirectly through intermediate products to imported or domestically-produced forest products. There are virtually no shipments of roundwood to overseas markets. Exports of Australian forest products netted AUD 205 million in 1979/80. Woodchips (65%) and paper (17%) were the main export earners (Department of Primary Industry, 1981).

The interdependencies existing in the Australian forest sector can be illustrated using data from the 1974/75 input-output tables for the Australian economy. Table 3 indicates that the majority of the sector's production is in the form of intermediate goods. Consequently, any changes in demand for products of other industries will directly affect the demand for forestry and wood products. Thus it is necessary to develop a forest sector model which recognizes internal interdependencies on the one hand, and allows for interactions with other sectors of the economy on the other hand.

AN AUSTRALIAN FOREST SECTOR MODEL

The present intention is to construct a forest sector model which contains five basic modules or submodels. These are (i) the demand for forest products, (ii) the forest product market, (iii) the forest industry, (iv) the wood market, and (v) forestry. These five modules can be viewed as an interdependent system, which exhibits considerable hierarchical structure. Figure 1 depicts the arrangement of modules.

Demand for forest products

The demand for forest products consists of domestic demand (which will be derived from a national multisectoral model) and foreign demand (which must come from a multinational trade model). Such demand is essentially a

Table 3. Interdependencies within the Australian Forest Sector.

INPUT / OUTPUT	forestry and logging	sawmill products	plywood veneers & boards	joinery & wood products	total domestic sales
Wood industries (sales within industry)	52%	28%	47%	4%	27%
Building & construction	5%	49%	9%	56%	39%
Furniture	-	5%	31%	3%	6%
Other intermediate demand	17%	13%	3%	14%	13%
Final demand	26%	5%	10%	23%	15%
Total domestic output	100%	100%	100%	100%	100%

Source: 1974/75 Input-Output Tables for Australia

function of demographic factors, substitution effects, technological changes, relative domestic and world prices, and local costs. The interdependency of this demand module with other models of the regional, national and international economies will be elaborated upon shortly.

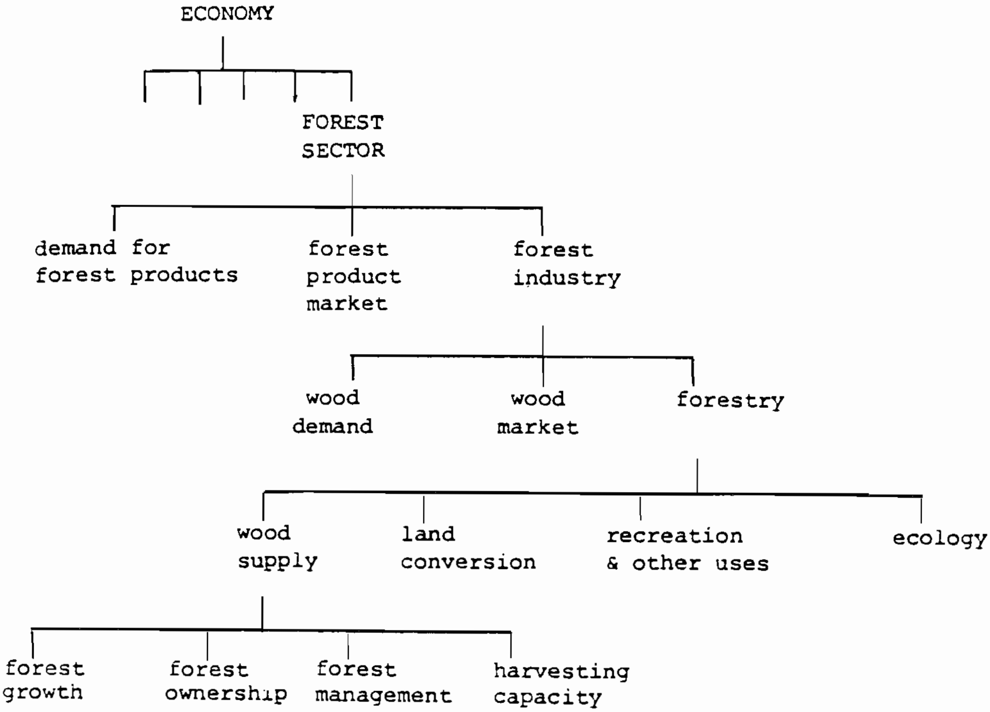

Figure 1. The hierarchical structure of forest sector analysis

Forest industry module

The supply of forest products also relies upon both domestic and foreign sources. Imports are determined by the inability of domestic supplies to satisfy domestic demand. Domestic supplies of forest products are computed in the forest industry module, where submodules for wood demand, the market for wood, and forestry are located. The position of the forestry submodule is intended to signify that the concept of forest products not only includes traditional products like roundwood, joinery, furniture and paper, but also other goods and services provided by forests (Grossmann, Lönnstedt and Seppälä, 1981). The social and ecological benefits of forests are often understated. It is intended to classify these as forest products.

The forest industry will thus be subdivided into the following three categories: (i) fiber-based products, (ii) mechanical wood industry, and (iii) other goods and services. Fiber-based products include pulp, paper, paperboard and the wood-based products of the biochemical industry. The mechanical wood industry produces lumber, plywood and wood-based panels. The FAO classifications will provide further guidance. Other goods and services include tourism, recreation, groundwater conservation, soil preservation and climatic improvements.

Forestry module

The forestry module is of the utmost importance, since it is here that the competing interests for forest use must be resolved. Forests are a versatile resource which can fulfil a variety of useful functions. In the forestry module, wood supply calculations are considered jointly with other land-use strategies, recreation and tourism, ecological balance, and other uses of the forest resources.

The wood supply submodule is divided into four parts: forest growth, forest ownership, forest management and harvesting capacity. The last two parts represent vital considerations in the wood supply submodule, since they determine the fundamental cutting, rotation and regeneration strategies.

Model overview

The nature, location and extent of forests in Australia accentuates their role as a fundamental regional resource. We have outlined a forest sector model which examines the interdependencies within the forests themselves, the resulting forest industries, and the markets for forest products. In doing so, we have so far ignored the effects of other economic activities, demographic trends, the labor market, energy, and trade between regions and nations. It is therefore appropriate to extend our system of models to take these additional interdependencies into account.

A FULLY INTERDEPENDENT SYSTEM OF AUSTRALIAN MODELS

When we come to consider the relationship of the forest sector to other sectors of our economy, it is important to recognize that forestry is a regional activity. Distinctions are often made with respect to the mobility of industries (Tinbergen, 1967, Karlqvist et al, 1978). World industries are regarded as free to locate in any nation, national industries in any region, and so on. The forest industry is not footloose, but is strongly tied to the locations of the forests themselves. It is in this sense that it must be classified as regional, even though its final products may be transported between regions and nations.

We shall therefore begin the construction of our interdependent system by linking the forest sector model to a multiregional model. However, decisions taken at the national level impose binding constraints on the feasible development patterns in each region and, in particular, the forest sector. The addition of a national multisectoral model to our interdependent system will cater for these constraining influences. Since national development is also sensitive to the shifting patterns of international trade, a further model dealing with world trade will be needed. To represent all these interdependencies, we shall take advantage of some of the author's earlier work on hierarchical systems (Batten and Andersson, 1981).

Our final multilevel modeling system is depicted in Figure 2. Although this representation successively disaggregates the development problem, each model may still be seen as an important component of a fully interdependent system. The forest sector model has been linked directly to the world trade model to allow for explicit consideration of the export potential of Australia's forest products. This provides some scope for "bottom-up" adjustments. An additional model, designed to analyse structural changes in the forest sector, has also been included for future consideration.

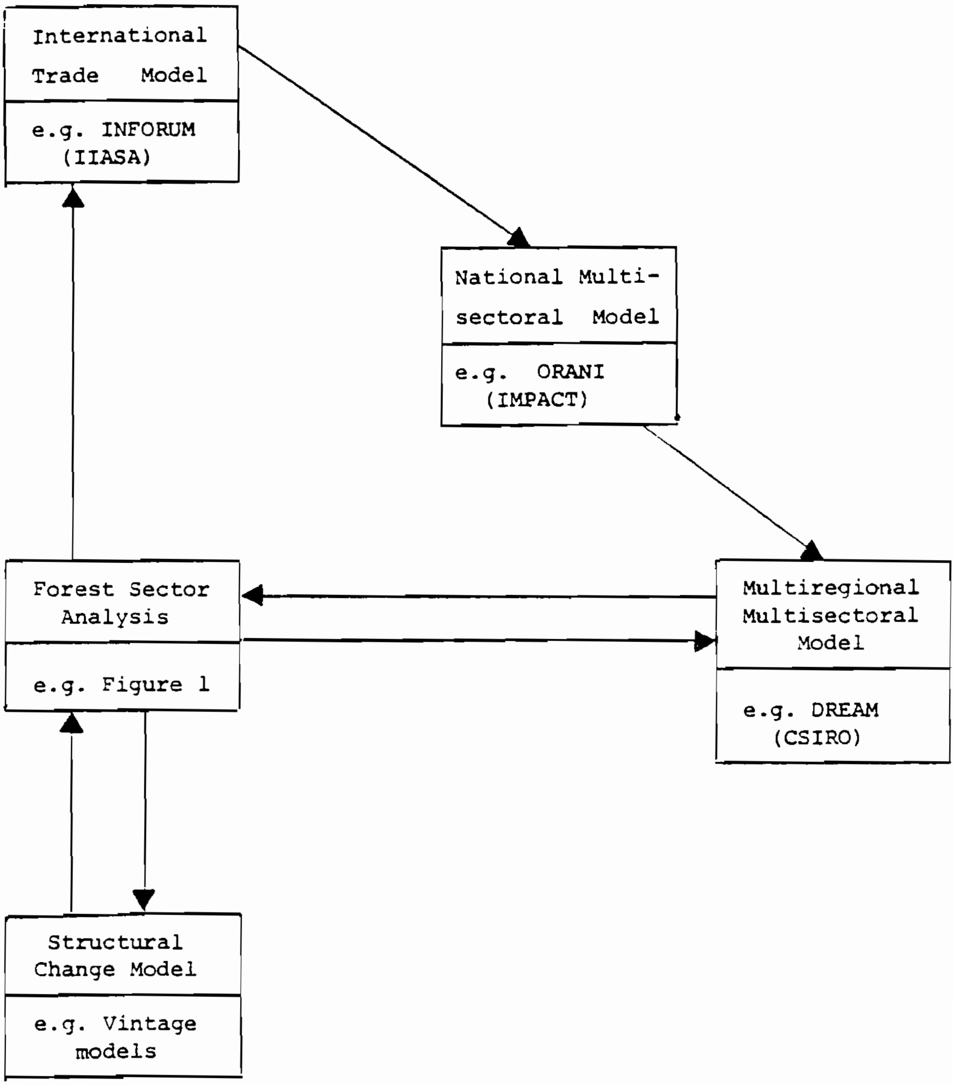

Figure 2. An Interdependent System of Models

A brief description of the existing models which are intended to fulfil these modeling functions at the multiregional, national, and international levels follows.

Multiregional multisectoral model

The DREAM (Dynamic Regional Economic Allocation) model integrates an interregional system of dynamic input-output balances together with certain basic relationships between the population, the workforce, and the levels of production and investment (Sharpe and Batten, 1976; Karlqvist et al, 1978). This optimization model was formulated as a tool for analysing the feasibility and consistency of various trade-offs between national and regional objectives.

A distinction is made between national industries, which can locate in any region, and regional industries, which are closely tied to one region. This allows the forest industry to be clearly distinguished. The model has been used extensively in various Australian studies by the author and some of his colleagues and, in particular, has been adopted in a comparison of both equity and efficiency solutions under various scenarios of population growth and activity in the housing and construction industry (Sharpe, Ohlsson and Batten, 1979).

National multisectoral model

The ORANI model is a sophisticated dynamic input-output model designed to provide projections of the effects of various economic policy changes on a wide variety of national economic variables (Dixon, 1980). The initial theoretical base was the MSG model (Johansen, 1974), but this model has been extended and modified by the IMPACT team in Australia. The result is an extremely versatile national model which can distinguish between short and long term effects of a policy change.

A typical ORANI result is of the form: given a policy change A in the macroeconomic environment B, then in the short-run variable C will differ by x per cent from the value it would have had in the absence of a policy change, while in the long-run it will differ by y per cent. Among the policy changes, A, which can be considered are tariff changes, exchange rate movements, changes in the level and composition of government expenditure, and changes in tax or wage policy. Examples of projectable variables, C, are rates of industrial outputs and investments, demand for labor by occupation, the balance of trade, aggregate employment and the rate of inflation.

International trade model

The INFORUM international trade model is designed to link various national input-output models (Nyhus and Almon, 1980). Developed jointly by the University of Maryland, IIASA and several other institutions, INFORUM computes "world prices" as seen by each importing country for each product. It takes total imports and domestic prices of each country for each product as given. The model then focuses on forecasting exports by commodity for nine major developed market economies and a rest of the world region. It is econometric by nature. The possibility of using the INFORUM model to generate world trade scenarios for forest products has already been considered (Nyhus, 1980).

CONCLUDING REMARKS

The hierarchical system of models proposed in this paper for the interdependent analysis of development options in the Australian forest sector is somewhat ambitious. Initially, modules for the supply of, and demand for, forest products will be simple, since the human resources available for this modeling exercise are very limited. As more resources become available, the fully interdependent system of models will be implemented. Some realistic scenarios of Australia's potential role in the world trade of forest products will then emerge (Batten and Waugh, 1981a,b).

The final system of models will be capable of generating scenarios of both short-term and long-term developments in Australia's forest sector. Forest industry capacity and forestry utilization strategies will be determined simultaneously, using an interdependent system which will be capable of identifying tradeoffs between various conflicting interests and objectives. There will be many critical assumptions associated with the conditional forecasts generated. The final results will be viewed as a set of feasible scenarios for Australia's forest sector, and not as any single prophecy of the future.

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IMPLAN: AN INPUT-OUTPUT ANALYSIS SYSTEM FOR FOREST SERVICE PLANNING

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ABSTRACT — IMPLAN, a computer-based system for developing non-survey input-output models, is discussed. The contents and procedures used to develop the extensive nation-wide data base are identified and the analytical capabilities of the system described in the context of Forest Service planning efforts. Finally, possible extensions of the system are noted.

INTRODUCTION

The USDA Forest Service has developed a computer-based system, referred to as IMPLAN, to assist its land and resource management planning efforts involving economic impact assessment. The IMPLAN system utilizes input-output analysis procedures and provides forest planners with the capability to develop non-survey based interindustry models and apply them to the evaluation of alternative management programs. This paper provides a general overview of the data, model building procedures and analysis capabilities that comprise the IMPLAN system.

Input-output models have frequently been used to describe the role of forestry activities in regional economies (Elrod, et al, 1972; Troutman and Porterfield, 1974). Input-output models have also been used to evaluate forest policies and programs (Schallau, et al, 1969; Connaughton and McKillop, 1979). The usefulness and applicability of input-output analysis to Forest Service planning has been demonstrated (Palmer and Keaton, 1978; Alward and Stewart, 1978). Indeed, several of the planning requirements of the National Forest Management Act of 1976 (P.L. 94-588) and its implementing regulations (36 C.F.R. 219, Subpart A, September, 1979) require economic analyses of proposed plans such as those that can be performed using input-output techniques.

Many applications of input-output models have utilized primary data obtained through direct surveys. Consequently, the cost in terms of money and manpower for these studies has been substantial (Bourque and Hansen, 1967). Various techniques for constructing models using secondary data have been proposed (Czmanski and Malizia, 1969;

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Richardson, 1972) and applied, significantly reducing the cost of obtaining a useable model. The debate about the veracity of secondary data models compared to primary data models continues (Schaffer and Chu, 1969; Miernyk, 1979). Given the magnitude of the planning task[3/] confronting the Forest Service, however, the cost of preparing the required number of models using primary data procedures was clearly prohibitive. Consequently, a data base of economic information relying upon secondary sources was developed[4/] as well as an efficient software system to perform the required computations. The resulting IMPLAN system has the capability of producing a non-survey based input-output model for any region of the United States, with the greatest degree of geographic resolution being a single county.

DATA BASE

The IMPLAN data base consists of two major parts: (1) a national-level technology matrix and (2) estimates of sectoral activity for final demand, final payments, gross output and employment for each county. The data represent 1977 county level economic activity for four hundred and sixty-six sectors.

The national technology matrix denotes sectoral production functions and is utilized to estimate local purchases and sales. This 466-sector, gross domestic based model was derived from the Commerce Department's 1972 national input-output model (U.S. Department of Commerce, 1979(a)). The "use" and "make" tables were rectified to an "industry by industry" basis and updated to 1977 using relative price changes and the RAS procedure (Stone and Brown, 1962) with the 1977 National Income and Products Accounts (U.S. Department of Commerce, 1977(b)) information used as control totals. Aggregation of some agriculture, construction and manufacturing sectors, and disaggregation of the mining sectors resulted in the reduction in the number of sectors from 496 in the Department of Commerce tables to 466 in IMPLAN. The matrix is a highly disaggregated representation of national average sectoral input and output technology and it is on the basis of these production functions that regional purchase patterns are estimated.

3/ Approximately 124 forest plans, 9 regional plans and a national program.

4/ This was developed by Engineering-Economics Associates of Berkeley, California. This use of the company name is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

Estimates of economic activity and production employment for each of the 466 sectors for all states and every county within each state were made for the components of an input-output table listed in Table 1. The estimates of economic activity for states and counties were made through a "downward movement" approach beginning with total national activity and disaggregating to states and ultimately to counties with control totals employed at each level. As previously noted, the updated 1977 national table was benchmarked with the 1977 National Income and Product Accounts. Since comparable accounts are not available for states or counties, the most suitable regional measures of economic activity were used to disaggregate the national production and demand activity, first among states and then among counties within each state.

Table 1 -- Contents of the IMPLAN Data Base for each U.S. County

A. Final Demand

1. Personal Consumption Expenditures
2. Capital Formation
3. Inventory Change
4. State and Local Government Expenditures
5. Federal Government Expenditures
6. Foreign Exports

B. Final Payments

1. Employee Compensation
2. Indirect Business Taxes
3. Property-Type Income

C. Total Gross Output

D. Production Employment

Gross output and employment estimates utilized several sources, principally censuses. For example, agriculture sector activity used the Census of Agriculture (U.S. Department of Commerce, 1977(b)) and the Agricultural Statistics (U.S. Department of Agriculture, 1979). Gross output measures for most other sectors[5/] utilized proxy measures derived from employment and payroll data, principally the national summaries of the County Business Patterns (U.S. Department of Commerce, 1977(a)) and employment data from the Dun and Bradstreet Corporation (1977). Some sectors could be related to specialized data sources such as the Census of Housing (U.S. Department of Commerce, 1970) for owner-occupied dwellings and the Census of Governments (U.S. Department of Commerce, 1977(c)) for government-related sectors. All data was adjusted to the 1977 base year and unreported data was estimated utilizing the RAS procedure.

Final demands were estimated, consistent with control totals from the National Income and Product Accounts, by updating the 1963 Multi-Regional Input-Output data (Polenske, 1970) using the RAS procedure as suggested by McMenamin and Harring (1974). The three components of value added were allocated on the basis of gross outputs. Both final demand and final payment estimates were disaggregated using the "downward movement" approach.

In its entirety, the IMPLAN data base provides a comprehensive, nation-wide set of input-output information which can be used to construct non-survey based regional tables. The national technology matrix is maintained at the highly disaggregated 466-sector level of detail which greatly reduces aggregation errors caused by using 1- or 2-digit SIC (Standard Industrial Classification) industry groupings. Consequently, the industry-commodity relationship is much more consistent than in highly aggregated models. The hierarchical nature of the data base, achieved by the use of published control totals at each level of disaggregation, results in a data base that permits the construction of models that are consistent both in terms of definition and activity. These principal aspects result in significant improvements over the data used in many previous non-survey input-output studies.

DATA REDUCTION

The IMPLAN software system was designed to serve three functions: (1) data retrieval, (2) data reduction and model development, and (3) impact analysis. The first two functions are discussed in this section and the third in the following section.

5/ Bureau of Economic Analysis input-output sectors 3.00 through 77.05, excluding sectors 11.00, 12.00, 65.01 and 71.01. (U.S. Department of Commerce, 1979(b)).

The data retrieval system was designed so that the user could have access to input-output data for any U.S. state, county or combination thereof. The study area data is referenced via a standard set of state and county codes with the extracted data treated as control totals for the region being analyzed. Modification of data, if desired by the user, is permitted.

Utilizing the national technology matrix and the regional control totals, a data reduction method is employed to develop a regional input-output table. The method used exploits the property of "openness" displayed by regional economies compared with the national economy (Richardson, 1972). Regional economies exhibit much greater propensities to import and export than is observed at the national level. Based on the assumption that trade balances are the principal difference between national and regional purchase patterns (that is, industry production functions are identical but regional imports and exports make local interindustry transactions different), the supply-demand pool technique (Schaffer and Chu, 1968) for data reduction was adopted.

This method for constructing a regional table begins with the national technology matrix and regional data for gross outputs, final demands and final payments. Regional data for all 466 sectors is sorted with respect to gross outputs. If the sectoral gross output is greater than zero (firms producing the commodity exist within the region), the corresponding column of direct coefficients is extracted from the national matrix. Using regional gross outputs and the abbreviated matrix of national direct coefficients, regional purchase transactions are computed. This transactions matrix is then scanned row by row. If the industry represented by any row has zero regional gross output (the industry does not occur within the region) the estimated purchases of that commodity are assumed to be non-competitive domestic imports and are shifted from the regional transactions matrix to final payments. If the gross output is positive and the commodity balance shows a surplus[6/], the domestic import purchases are assumed to be zero, the regional transactions estimated with national direct coefficients are left unchanged, and the surplus assumed to be domestic exports. If the commodity balance indicates a deficit, the regional final demands and transactions estimated with the national coefficients are proportionately reduced across the row to obtain a balance, and the differences assumed to be competitive domestic imports. The result of this process is a matrix of local transactions between regional industries plus estimates of both competitive and non-competitive imports as well as exports.

The data reduction procedure used in IMPLAN produces a complete table of regional input-output accounts including a transactions table, the final demand and final payments quadrants, and the fourth quadrant.

6/ Regional gross output is greater than regional final demand plus intermediate demand estimated with national direct coefficients.

In addition to this typical table of accounts, detailed reports of sectoral competitive and non-competitive import purchases are given. Based upon the regional accounts, the predictive input-output model can be derived by computing the standard Leontief-type inverse and calculating various income and employment multipliers. If appropriate, the number of sectors in the model can be reduced through aggregation prior to inverting the matrix.

Several limitations to non-survey data reduction techniques have been noted (Richardson, 1972; Fisch and Gordon, 1978) and the supply-demand pool procedure likewise has limitations. One principal limitation of the supply-demand pool technique is that cross-haul conditions are ignored while evidence suggests that this may be a common occurence in regional economies. This arises from the technique's method of allocating local production to meet local requirements before imports or exports are estimated. Through the use of a highly disaggregated technology matrix and a consistent data base, the IMPLAN system has mitigated though not eliminated many limitations noted by others. For example, Richardson (1972) commented that the use of the national technology matrix may overestimate the interdependence of a regional economy. Similarly, Miernyk (1976) criticizes the supply-demand pool technique assumption of proportionate imports by all purchasing industries. Continued improvements are being sought to enhance the system.

ANALYSIS

The analytical capabilities of the IMPLAN system can be classified into two broad categories: (1) the estimation of impacts originating from changes in final demands, and (2) the evaluation of constraints upon sectoral gross outputs. Estimating the regional economic impacts of disturbances in the final demand vector caused by resource management actions is the most frequently used form of input-output analysis employed in Forest Service planning studies. These demand disturbances arise from such activities as timber harvesting, grazing and recreation, as well as direct budgetary expenditures for goods and services. Economic impacts are expressed by the changes in regional income and earnings, employment, gross output and various other parameters.

Input-output models are typically used in Forest Service planning studies to estimate the regional economic effects of implementing optional management plans. These plans describe the intended management activities on a National Forest along with the expected outputs, resource uses and budgetary expenditures. Economic impacts are characterized as changes (increases or decreases) from current conditions. Planning teams frequently employ input-output models in other ways. The models provide excellent descriptions of regional economic structure, giving planning teams valuable information for formulating Agency policies regarding economic growth or stabilization. Opportunities for developing markets for forest products can often be identified through the use of input-output accounts. Major structural changes in an economy, caused by such events like mine construction or ski area development, can be investigated by generating hypothetical models that characterize the introduction of new industries. Input-output models have become integral components of the formal planning models employed by the Forest Service.

The linkages between Forest Service management actions and corresponding estimates of net changes in regional final demands are critical components in the use of input-output analysis for impact estimation. These disturbances in final demand arise from two principal sources: public expenditure effects and private sector output effects (Cartwright, 1979). Public expenditure effects arise from demand disturbances caused by government purchases of goods and services. For example, timber stand improvement projects or the construction of recreational facilities involve purchases for labor, materials and so forth which can directly be transformed into a demand disturbance vector. Private sector output effects are somewhat more complex. These effects stem from the use of forest resources and indirectly (from the viewpoint of the Forest Service) result in demand disturbances. For example, the Forest Service's provision of various "factors of production" such as stumpage for wood products, water for municipal and domestic uses, and forage for red meat production must be traced to its final regional economic use, either directly to exports or via "forward linkages" and "stemming-from" effects (see, for example, Roesler, et al, 1968). The effects of the use of forest resources for recreation can be directly transformed into demand disturbances by deriving a typical "bill of goods" purchased locally by the recreationist during the pursuit of such activities. In all cases the demand disturbances represent regional market transactions expressed in purchaser's prices with appropriate transportation and trade margins.

Traditional applications of input-output models, utilizing demand disturbances as the source of interindustry effects, contain an implicit assumption of sufficient resource supply to permit attainment of an equilibrium economy. As is often the case with forest resources, some of the primary resource supplies may be restricted within a regional economy (for example, the amount of water may be restricted). If the change in forest output is used, under these circumstances, to derive a disturbance in demand and the model used to estimate the resultant multiplier effects, the backward linkages would usually indicate a total demand for the resource exceeding the original change. The IMPLAN system has been designed to perform analyses under these conditions by permitting the user to link the change in resource output directly to a change in sectoral gross output rather than a change in final demand. The input-output model is then used to estimate the maximum level of delivery to regional final demands attainable given the constrained level of gross output. This kind of analysis is often applicable to economies that are highly dependent upon primary resources.

The economic effects estimated with IMPLAN are described by parameters typical of input-output studies. They are structural in nature, permitting multiplier effects to be traced throughout the various regional sectors. Direct, indirect and induced changes in gross outputs and final demands, employment and import requirements, income and earnings are the most representative parameters used to describe impacts. The availability of a complete table also permits calculation of gross regional product. Induced effects are computed using a modified "Type III" multiplier procedure (Miernyk, 1965), iteratively solving the open model to capture the effects of induced consumptive spending. Detailed employment analysis is possible by tracking employment requirements among various occupations, and accounting for the effects of either in-migration of workers or re-employment of unemployed local labor. In combination, this information provides a comprehensive, detailed account of potential regional economic impacts.

IMPLICATIONS AND EXTENSIONS

The IMPLAN system provides the user ready access to detailed non-survey based input-output models of regional economies. The availability of an extensive data base permits construction of detailed models that portray the structure of the regional economy under study. The data reduction technique takes explicit account of the "open" nature of these economies, tracing both intra-regional flows as well as imports and exports. The models also permit analysis of Forest Service activities, either individually or in combinations such as a management program. The construction and use of these models are relatively rapid and inexpensive, and the system is available throughout the Agency via distributed computer network. A major advantage of the system is to permit resources to be devoted to the utilization of input-output models in planning rather than to model construction.

Possible extensions in the use of IMPLAN data and models involve more extensive uses of impact models in Forest Service planning. To date, most impact analyses have focused upon local area studies. In the context of a multi-level planning system (see the article by Hof in this volume), the usefulness of input-output models will certainly become apparent. State and regional models will likely become closely linked to the planning model to estimate the economic implications of various Forest Service policies. Similarly, structural analyses of timber policies investigated by the Timber Assessment Market Model (Haines and Adams, 1980) may also be possible. It appears that the availability of input-output models on a regional basis will permit a wide breadth of innovative uses in natural resource management.

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CAN WE NOW IDENTIFY THE BEST APPROACHES TO MODELING NATIONAL FOREST SECTORS?--DISCUSSION

Bruce Lippke[1]

The simple answer to the above question is no, it is too soon to identify the best approaches to national forest sector models. But, we should continue to have annual discussions on this topic until the answer is yes. Progress may not be that slow, but it has only been in the last few years that we have had more than a handful of people interested in the subject. It has not been easy to establish interest in the macroeconomic concepts of forest products and in timber supply and demand balances.

So, we still need more diversity of approaches and more communication between different researchers and critics if we are ever to become more discriminating. And, I believe that we will have to become very discriminating if we are ever to develop adequate national forest sector models. But, we have already come a long way. Research is ongoing on several structural approaches to interconnect supply and demand by region. There is work underway on several approaches to model the supply response to price, which is certainly a key issue. But there are still many aspects of the supply response, such as forest utilization, recovery, and substitution, that are dynamic and remain almost untouched.

Mostly, I think we need to be more open to a broad range of assumptions on key parameters to demonstrate which are the most important assumptions that effect the results (causing a large range of uncertainty) and which are relatively less important from a national model sense. There are many important micro questions to specific groups of people that are still relatively unimportant to the national aggregates and need not be part of a national model. Showing the uncertainty range in results as a response to uncertainty ranges in the assumptions is currently more important than improvements in model structure.

There is no meaningful equilibrium solution in the future, and, if there is one for the past, we are still not capable of identifying all of the important parameters that determined it. As a consequence, there is probably too much current emphasis on national or international optimization. It is premature to worry about optimization over a subset of parameters, when too many important assumptions are still being left out or inadequately described. There is little value in finding the optimal "extreme point" on the wrong surface for optimization.

This should not be interpreted to mean that transportation or product flow optimization systems are meaningless, since they may be sufficient as simulation tools. But our understanding of the sensitivity to key parameters is still too crude to warrant much emphasis on optimization or point estimate forecasts compared to showing the impact of a broad range of assumptions on inputs and structure.

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If the systems analysis approaches are better to show the true range of uncertainty, it would have to be an implicit part of the philosophy of the systems analysts rather than the models. I am sure you can hide key assumptions just as easily in systems analysis approaches as in econometric approach. There is a critical error distribution around regression coefficients, or engineering coefficients and none of these error distributions are adequately known.

I have also noted in meetings such as this one that we are a lot better at talking about uncertainty than we are when it is time for final publication. In the final publication, there is always that due date to cut off the effort at full communication. There is also a page limit to worry about. But even worse, there are the prior positions that have been taken over time that are hard to change, like a "cultural conservatism", or in other words politics. All of these realities suppress communication of the full range of uncertainties in describing the practical or the potential outputs.

Words like "total accounting" are great model buzz words, but the question remains, is it really total? Total accounting does nothing to solve the important issues even it were total, which it usually is not. Where did the capital resource come from, or labor, or land, or the right to manage any of them, what where the alternative uses? Were all of the alternative policies and alternative uses of the resources explored? It would seem shocking to worry about more total accounting for an LDC model than for a developed country model. For most LDCs, capital should be the most scarce resource and at least more so than for a developed country.

The TAMM model used by the Forest Service as a U.S. national model certainly does not develop full accounting nor did they explore a wide-range of assumptions. But, they did try to demonstrate some impact of investment feedback. It is easy for me to say that all of the improvements described for the TAMM model are important. But are they the most important? We may not know that in advance until we test the sensitivities. For example, if stumpage is not separated by quality to distinguish between solid wood values distinctly from fiber values, then many of these changes are not even close to "most important".

The major TAMM model problems that characterize a very wide range of uncertainty include at least:

1. Demand--too optimistic
2. Solid wood versus fiber resource separation
3. Product recovery and forest utilization response to price
4. Timber growth initial assumptions and investment feedback
5. The beginning inventory measurement accuracy
6. The characterization of acres managed intensively
7. The supply response relationship to more than just an old growth inventory
8. International supplies and demands

And this list could go on and on, but my value judgements place these as most important.

Similar problems or questions can be raised for the systems analysis models as well. What we need is more discussion on what is most important to model and what can we leave out without loss of information. Not everything needs to be solved simultaneously. Not everything needs to be a part of national or international models. Demonstrating sensitivities is a necessary step in learning to discriminate how to build an investment model, but it is certainly not sufficient without a great deal more communication about what is most important.

APPROACHES TO MODELLING NATIONAL FOREST SECTORS - DISCUSSION

William McKillop [1]

Abstract. A number of features of the current TAMM model, together with future modifications and extensions make it the most effective approach available for modelling the U.S. forest sector. For many other countries, inadequate data bases, or significant governmental regulation of market processes may make a conventional econometric approach infeasible or inappropriate, but the general principles of econometric modelling provide useful guidelines for a wide range of situations.

In terms of modelling the forestry and forest industry sector of the United States, the TAMM model (Adams and Haynes, 1980) is clearly the most comprehensive and effective approach that could be adopted at this time. Three of its most attractive features are (a) the modelling of supply on a regional basis, (b) the linking of lumber, plywood and stumpage markets, and (c) the use of a biological simulator to represent the effect of timber output levels on forest growth and yield. These features provide a conceptually meaningful portrayal of domestic supply. Provisions for handling processing capacity, product recovery factors and residue utilization add elements of realism that are highly desirable. In addition, the utility of the model is greatly enhanced by its ability to simulate the effects of parametric and policy changes.

Future modifications and extensions of TAMM, which have been announced at the conference, are of substantial interest. Of particular importance are (a) improvements in the analysis of domestic demand, (b) expansion of the pulp and paper sector (c) more comprehensive treatment of foreign demand and supply, and (d) revision of the growth and yield simulator. Such improvements suggest that in the future, TAMM will represent a near-optimal approach to forest sector modelling in the United States. But this does not mean that the approach is necessarily appropriate for sector modelling in other countries.

Viewing the issue in the broadest of terms, one must recognize that for many countries an econometric-simulation approach may not be appropriate or feasible. Conventional econometric modelling requires a good data base. It also requires an economic framework that is amenable to estimation in the sense that it does not change freely in structure and is not dominated by large, unpredictable, exogenous forces.

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This type of modelling is thus most fruitful for well-developed, free-market economies where there is not a strong degree of governmental intervention in terms of such things as price controls, subsidies and investment planning. But simulation models are only as good as the estimated parameters that support them. Thus an econometric-type of approach which seeks to specify and quantify relationships should remain the goal of forest sector modellers.

Careful specification of structural relationships (on the basis of theory and observation) is desirable even when statistical estimation is impossible because of inadequate data. In this case judgmental estimation, together with sensitivity analysis, may be used to construct preliminary models, and at the same time may indicate what data needs are most pressing. In cases where data are readily available, but where market processes are modified by governmental direction, the issue becomes one of finding suitable proxy variables or modifying estimation techniques. For example, indicator or dummy variables may be used to represent periods of governmental intervention; or constrained estimation of parameters may be attempted. This type of analysis is not an easy task but it represents an interesting challenge to forest sector modellers.

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PART III

DEVELOPING REALISTIC LONG-TERM SUPPLY RESPONSE ESTIMATION CAPABILITIES

INTRODUCTION

Bruce Lippke[1]

Part II of this book was concerned with the development of forest sector models. The emphasis of Part III is on some of the subproblems in model development, specifically on the development of "realistic" long-term supply response estimation capabilities. I emphasize the word realistic with both rigor and good humor in mind since it will take both to achieve realism. A realistic model may be a desirable goal, but is it reachable?

It is important to keep in mind the time frame of the historical analysis and projections when talking about supply responses. I participated in many econometric modeling efforts beginning with the early development of U.S. international forecasting models, including Wharton, DRI, Chase Econometrics, the Maryland Inter-industry Model, and on and on. Everyone is supposed to know by now that if you want an outlook for the very short term, say tomorrow, the naive model that projects the same change for tomorrow as you saw for today has the best accuracy in the short run. Unfortunately, that doesn't capture any information from an information theory point of view. It cannot capture the causes for turning points, which is the practical purpose for most models.

To forecast a little further out, call it the short term, say up to a year or two, the whole science of econometrics has developed, which tries to characterize the causes of changes of the past and get on track with those causes and changes to forecast changes in the future. But the time horizon is still for a relatively short term extrapolation of no more than a couple of years.

For the longer term forecasts, it is much less relevant where you are within the current short term causes or constraints, whether they are economic or political. It becomes much more relevant what the long term potentials are and how technology changes can impact those potentials. So long term models put a lot more attention on technology issues, ultimate potentials, and a lot less emphasis on current economic or current political restraints. You have got to throw off current constraints without losing sight of potential limits and future constraints to project for the long term, say over ten years out.

To get from the short term to the long term, you have to bridge from one structure to another. Stated simply, the science of this middle time period is very thin. Learning what to keep from the short term structure and what to discard and what to use from technology in order to characterize the long term should be the key to "realistic" projections and simulations.

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IMPROVING APPROACHES TO ESTIMATING TIMBER PRODUCTION OPPORTUNITIES ON PRIVATE FOREST LANDS

George Dutrow and Merle Conkin[1]

Abstract: This paper describes methodology and results of a recent study to estimate nationwide opportunities to increase timber supplies through economic investments in forest management. Joint sponsorship of the research by the Forest Productivity Committee of the Forest Industries Council and the U.S. Forest Service provided a broad information base, enabling the authors to specify silvicultural opportunities, acreage in need of treatment, incremental yields, forest management costs, and timber values. In addition to summarizing methodology and results, shortcomings in the analysis and needed improvements are discussed.

Additional keywords: timber supplies, economic returns, silvicultural practices, forest planning, forest resource management, forest industry, nonindustrial private forestry.

INTRODUCTION

Early U.S. Forest Service projections forewarned the public of rapid escalations in demand for wood products. Prices for these products, and stumpage, would become inflationary. The Forest Service called for concerted efforts by landowners across the country to increase timber production to avoid timber famine, devestating price hikes, and high levels of net imports. Although timber famines never materialized, questions emerged that continue today to perplex forestry planners and policymakers. Namely, what are the nationwide opportunities to increase timber supplies? Which of these opportunities are profitable? And, what are the capital requirements to implement the opportunities?

Since the Forest Service was responsible for studies warning the public of timber shortages accompanied by rising prices, the Agency was also the recipient of questions and suggestions about appropriate corrective actions. Private landowners, forest industry, and Congress wanted to know what could be done about increasing our supply of timber and avoiding undesirable economic consequences. The Forest Service initiated research to address these concerns. Results suggested that numerous opportunities to increase timber production existed, but the data base was sketchy and not compatible with projections of long-run supply. Silvicultural opportunities were defined but could not be linked to supply projections to determine the impact of additional supplies on price and trade balances or to estimate the profitability of additional forestry investments.

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In 1974, Congress mandated that the Forest Service systematically attempt to resolve these issues. The Forest and Rangeland Renewable Resources Planning Act of 1974, as amended by the National Forest Management Act of 1976, commissioned the Forest Service to integrate timber supply activities on national forests with those in the private sector. This integration requires coordinated and extensive efforts to estimate increases in national timber supplies that might be achieved by applying more intensive cultural treatments on commercial forest lands. Simultaneously, the question of whether or not these cultural treatments offered acceptable returns to investors must be considered. In response to the legislative mandate, the Forest Service assigned responsibility for the task to the Southeastern Forest Experiment Station's Economics Research Project at Duke University.

The critical importance of these questions to national forest planning and private timber investment decisions had not escaped the attention of chief executive officers of the forest industry. Leaders in the forest industry were particularly interested in potential increments to economic timber supplies and the associated capital requirements. Inventory data depicted growth exceeding drain for the nation as a whole, but industry recognized that a substantial amount of the growth was not economically available. Many tracts of timber were too small or too distant from the mills to be harvested economically; both public and private landowners were placing increasing acreages of productive forest lands "off limits" to timber management and harvest; significant portions of the timber growth were occurring on species that were unmerchantable or of extremely low value; and current technology limited utilization of much hardwood growth. Thus, although growth was exceeding drain, much of the growth could not be harvested or processed economically and did not contribute to the supply of available wood. Pinpointing opportunities to augment economic timber supplies would focus attention on this problem as well as offer remedial prescriptions.

The Forest Industries Council (FIC), consisting of leaders of forest industries and officers of the major industry trade associations, commissioned the FIC Forest Productivity Committee to gather and analyze data under the administrative auspices of the National Forest Products Association. However, industry's efforts to delineate economic opportunities to grow more wood and assess the impacts on future timber supplies required inventory data from major timber producing states and regions. Such data required access to Forest Service state inventories. Meanwhile, the Forest Service confronted major obstacles in obtaining information on incremental timber yields, forest management strategies, costs, and timber values which the forest industry could help obtain.

Industry and Forest Service leaders saw an opportunity to join forces in a cooperative approach and launched a major research study to estimate economic opportunities to increase timber supplies. Methodology and results summarized here were reported in depth in the FIC's "Forest Productivity Report" and the Forest Service's "1980 Resources Planning Act Assessment" and "An Analysis of the Timber Situation in the United States, 1952-2030." These documents are the products of a fully cooperative venture of the U.S. Forest Service, the Forest Productivity Committee of the Forest Industries Council, and the many foresters from industry, consulting firms, government, and universities that served on our regional panels and state productivity committees.

AN ASSESSMENT OF OPPORTUNITIES TO INCREASE TIMBER SUPPLIES

Methodology

Analysis by the FIC Forest Productivity Committee revealed that 25 states accounted for over 80 percent of the commercial forest land base and of the wood fiber removed annually. Thus, the study was limited to these 25 key states. The states encompassed by the study by major timber supply regions were:

Northeast: Maine, New York, West Virginia, Pennsylvania, and Kentucky

North Central: Minnesota, Michigan, Wisconsin, and Missouri

Southeast: Virginia, North Carolina, South Carolina, Georgia, and Florida

South Central: Alabama, Mississippi, Louisiana, Texas, Arkansas, and Tennessee

Rocky Mountain: Idaho and Montana

Pacific Coast: Washington, Oregon, and California

As a first step, the Forest Service established corresponding regional panels of recognized forestry experts from industry, government, and universities. Members of these panels attended 2-day workshops to accomplish two goals: (1) define opportunities prevalent in their respective region to increase timber supplies from existing stands and forests, and (2) specify these opportunities in sufficient detail for Resource Evaluation Units to estimate the number of acres in each regional opportunity based on forest survey data. To achieve these goals, panels had to specify items such as forest type and condition class, stocking, stand age, availability of seed sources, amount of competing vegetation, and other biological and management criteria for each treatment opportunity. This degree of detail enabled Resource Evaluation Units to estimate acreages for each treatment opportunity in each state by ownership, physiographic class, and site category.

Regional panels focused their attention on selecting treatments that served one central purpose: to increase timber supplies. Influences of timber production on other land uses could not be ignored, however, and panelists recognized three general constraints as they selected treatments to augment timber production. These were:

1. Management activities must be environmentally acceptable.

2. Silvicultural treatments must appear to be economically sound.

3. Treatments should be in addition to efforts already scheduled or planned. (This constraint attempted to isolate the additional timber supplies brought forth by additional expenditures.)

The second step was the establishment of state committees, consisting of local forestry experts from industry, government and universities, to further examine the opportunity acreages and recommended treatments resulting from the work of the regional panels. Under the leadership of the FIC Forest Productivity Committee, these state committees developed more specific management strategies and estimated costs and incremental yields. They first determined a range of costs that would be required to apply the treatment in their state. Such cost ranges were necessary to account for changes in topography or other natural conditions, for differences in tract size, and for alternative ownership objectives.

In estimating incremental yields, state committees again were forced to consider a range rather than a single value due to site variations, different forest types, and alternative management strategies and intensities.

State committees also had to address the question of stumpage revenues. In all cases, stumpage values were derived from whatever published sources could be found. For example, Timber Mart South provided the necessary stumpage price data for the Southeast and South Central regions.

To summarize data inputs, the regional panels and state committees provided five types of information critical to assessing opportunities to increase timber supplies:

1. Timber investment opportunities and associated acreages by state, site, physiographic class, and ownership category for each forest type and condition.

2. Prescribed management strategies for specific forest types and conditions.

3. Costs of applying the recommended treatments.

4. Estimates of yield response to the treatments.

5. Appropriate stumpage prices.

These were the data inputs necessary for the staff to implement an economic analysis of the investment opportunities. Our goal was to estimate the additional wood supplies and financial returns expected from treatments applied to existing forest sites. We assumed that a landowner is looking at his timberland and trying to decide the most profitable action, whether that be to improve the stand or to clear it and start over or to walk away from it and put his money into T-bills instead. Thus, his choice is what to do with what he has -- a marginal decision. The landowner is concerned with additional costs and additional returns associated with a given management action. All costs and yields tabulated were incremental -- that is, in addition to what might be expected if no treatment were applied.

The investment opportunities were categorized into generalized groups of forest management activities for tabular and summary presentations as follows:

1. Stocking Control. This treatment involved removals of competing trees through precommercial and commercial thinning.

2. Stand Conversion. Recommended management actions in this group included removal of undesirable, generally nonmerchantable forest types and reestablishment of the stand with a preferred species.

3. Regenerate Nonstocked Acres. This management option called for reforestation of acres which currently do not have a viable stand.

4. Harvest and Regenerate. This treatment required removal of mature and overmature stands and regeneration by either natural or artificial means.

Economic analyses were performed for 375 separate treatment opportunities to provide an assessment of potential increments to timber supplies and to ascertain which of the opportunities appeared profitable. Economic assessments were marginal analyses, with the financial results expressed in real terms. Investment lengths varied from stocking control regimes of ten years to some regeneration efforts requiring rotations in excess of 100 years. Several criteria of economic efficiency were calculated, but present net worth was the final standard of comparison. Real discount rates from 4 to 10 percent were used so that we could compare forestry investments with alternative opportunities. In addition, analysis of each treatment opportunity incorporated 21 different price assumptions, ranging from real price increases over the next 50 years of +5 percent to -5 percent per year. The combination of 21 price assumptions, 5 discount rates, and 375 treatment opportunities produced nearly 40,000 cash flow analyses.

A final methodological step had to be taken. If investors took advantage of the opportunities to grow more timber, significantly greater amounts of wood would begin moving to the market soon after the year 2000. This additional increment of wood, coupled with the long-run timber supplies already projected by the Forest Service, would dampen price expectations. Lower price expectations, in turn, would adversely affect the profitability or desirability of additional investments in forest management. Thus, it was necessary to combine base level supply projections with the potential supply resulting from additional timber management investments to assess the overall supply/demand/price impacts. The integration of the treatment opportunities data and timber supply projections was achieved through use of the Timber Assessment Market Model (TAMM) developed by scientists at the Pacific Northwest Forest Experiment Station and Oregon State University.

With more intensive management resulting from investments in treatment opportunities, prospective growth on treated acres would exceed expectations from current management levels. Effects of intensified forest management were simulated in TAMM by developing new per acre growth rates which equaled current trends plus additional growth from adoption of a mix of treatment opportunities. As additional acres were enrolled in more intensive management, future timber supplies were expanded, with a resultant downward pressure on expected stumpage prices. Identifying the economic solution was achieved through an iterative process based on determining those opportunities promising a positive present net worth at a real 4 percent discount rate assuming the future stumpage prices projected by TAMM. Completion of the iterative process provided estimates of future timber supplies given implementation of economically feasible management opportunities, probable stumpage and final product prices that would result, changes in forest product trade, balances, and a number of other projections important to formulating forest policy and measuring its effect.

Although the results of this study are detailed in other publications, some of the general findings should be of interest.

Results

The results of this study indicate numerous opportunities for investments in forest management which would yield 4 percent or more, measured in real dollars. If these investments were made, timber supplies would be increased substantially.

There are economic opportunities for more intensified forest management on 168 million acres of commercial timberland, some 33 percent of the U.S. total. With treatment of these acres, net annual timber growth would be increased by 12.7 billion cubic feet, an approximate 50 percent increase in total net annual growth. However, it would require several decades before the effects of investments in more intensified management were realized. Furthermore, substantial capital, $13.3 billion, would be required to do the job on all identified acres. About 16 million acres were initially identified for treatment but failed to promise financial returns of 4 percent or more.

The foregoing results apply to the Forest Service analysis of the data base for RPA Assessment purposes, and reflects the imposition of a 4 percent discount rate and inflation-free costs and prices. The Forest Productivity Committee analyzed the same data base, but imposed an approximate 6 percent discount rate. Furthermore, industry analysts included opportunities existing on National Forest System lands as well as those in private holdings. Nevertheless, findings are compatible, and resultant differences are as expected with a higher discount rate and larger land base.

The Forest Productivity Report identifies about 139 million acres which qualify as economic investment opportunities. Capturing these opportunities would require current investments of $10.3 billion and would increase growth by 10.9 billion cubic feet annually. These investments, again, would result in an increase in net annual growth of approximately 50 percent over current levels.

Both studies are in close agreement in terms of the predominate forest management opportunities and the category of ownership most in need of attention. About three-quarters of the economic opportunities on an area basis involve reforestation of nonstocked areas, regeneration following harvest of mature stands, and conversion of existing stands to more desirable species. Reforestation and conversion efforts would consume 88 percent of total expenditures and would provide about 90 percent of potential increases in timber supplies.

A majority of the opportunities for treatment and investment are on private nonindustrial ownerships, which collectively account for about 58 percent of the commercial timberland. A $10 billion investment in this ownership category would earn financial returns greater than 4 percent and would boost net annual growth of timber by over 9 billion cubic feet for the next 30-50 years. The remaining opportunities are on the commercial timberland in forest industry ownership and on the national forests, where the forest industry study identified some 28 million acres that qualify for more intensive management.

From a national viewpoint, there are numerous opportunities to make investments in forest management, especially on lands owned by the nonindustrial private sector. Most opportunities involve reforestation or conversion, but significant numbers of acres need stocking control treatments. Similar overall results characterize the timber supply regions and 25 states included in the study, but each region or state offers its own blend of silvicultural and economic influences on prescribed treatments and financial prospects. Furthermore, as determined by the Timber Assessment Market Model, intensified forest management leads to increased domestic production of wood products, lower prices, increased consumption, and reduced U.S. dependence on imports of wood and wood products.

It seems clear that our study attempted to provide necessary and important information for formulating forest policy and managing our commercial timberlands nationwide. However, it is just as clear that our study encountered numerous obstacles and exhibits serious shortcomings. Since obstacles and shortcomings can serve to guide subsequent studies to more valid and precise answers in the future, it is worthwhile to spend some time discussing the flaws.

Study Shortcomings

One notable shortcoming in efforts to identify opportunities for more intensive forest management is the absence of a nationwide system to collect treatment opportunity data as an ongoing process in forest survey activities. If treatment opportunity data were an integral part of survey plot assessment, clear linkages between inventory data and management opportunities could be established. Techniques to achieve this type of information are being examined in the various timber supply regions with apparent success at the Southeastern Forest Experiment Station. With standardized techniques and regular updating of the information on treatment opportunities, analysts would not have to rely on specification of intensive management options by regional panelists, who may or may not offer realistic assessments. Hopefully, identification of investment opportunities can be substantially improved for the 1990 RPA Assessment.

The results also exhibit some weaknesses with respect to use in policy decisions. Average values for site productivity, incremental growth rates, costs, and prices across a state or region are rarely indicative of conditions on any given ownership or site. Policies or programs formulated on state-wide averages may conceal exceptionally rewarding opportunities that exist on certain types of sites or in areas where market competition promises higher-than-average revenues. Furthermore, the acreage estimates are unrealistically high. Acre estimates in our study represent an outside or theoretical limit. Every acre of the given stand condition is tabulated. No accounting was made for tracts that are too small for economic management, too inaccessible to warrant investment, or likely to be converted to nonforest use. Thus, the opportunities represent potential maxima, not probable commitments to forestry. Actual commitment of acres to timber production or intensified management, especially by nonindustrial private owners, will only be a fraction of the acres tabulated. A valid method for estimating the probable number of acres that will be treated is vital, but currently unavailable.

The acreage flaw is serious. Advocates of reducing acres allocated to commercial timber production point to studies like this as supportive evidence. They argue that substantially greater timber supplies can be produced on fewer acres which are intensively managed. But, two elements are frequently overlooked. Operating on small or inaccessible tracts is extremely costly and usually unprofitable; and long-term investments in accelerated timber growth divert capital from other competing short- or long-term uses. These are among many reasons cited by nonindustrial landowners who elect not to invest in forestry even though the venture seems profitable. When these considerations are introduced, it becomes clear that the number of acres in a given ownership or stand condition is an overestimate of the number of acres that actually would be managed for additional timber production. Our data support the premise that more wood could be grown on fewer acres, but the inference that commitments of acres and dollars will occur and allow diversion of many forested lands to other uses does not automatically follow. Empirical evidence points to a contrary conclusion: many productive forest lands are not being managed or regenerated.

Despite this imposing list of caveats, the results of our study are being used to formulate forest policy and programs. The flaws and imprecise estimates do not detract from the overriding conclusion that there are numerous opportunities nationwide to invest in timber management practices that will yield good rates of return and result in major increases in the nation's timber supply. The 1990 RPA Assessment offers a real opportunity and need for methodological improvements in refining these estimates.

OBTAINING PRODUCTIVITY DATA FOR FUTURE RESOURCES PLANNING ACT ASSESSMENTS

Current plans for conducting the 1985 RPA Assessment and developing the associated Program call for substantial increases in the amount and quality of information. Central to these plans is establishment of goals for each of the outputs from forest and rangelands. For each goal, specific objectives in terms of timing and levels of production must be evaluated. This is an ambitious undertaking and will demand more and better information about resource management opportunities to achieve cost-effective increases in productivity. Timber is one of the outputs, and a realistic estimate of increased timber productivity will be critical information.

For the short run, i.e., the 1985 RPA, there is little that can be done to significantly improve the information on investment opportunities. Underway is a study to review the existing data and update, where feasible. This is being accomplished through mailed questionnaires to the state and regional committee members who participated in the earlier studies. At best, some updated information on costs and yields may be obtained; but there is little likelihood that the basic opportunity classes and acreages or associated management strategies will be changed.

In the longer run, it appears that two possible strategies are feasible to update and revise the data. Both strategies are oriented to obtaining the involvement of local forest managers as it is only through their expertise that a creditable data base can be built. This was the reason the original productivity study was oriented to the state level and implemented through state committees of local forest managers.

The first approach would be to basically redo the previous productivity study employing the same methodology and organizations. This would result in another joint Forest Service/industry effort, and it is estimated to require resources of the magnitude required by the previous study. The drawback to this approach is that it tends to focus on one aspect of the overall analysis and information base needed for a complete assessment of the resource or even the timber base. Thus, the burden falls on the study managers to assure that the results are compatible with the other parts of the supply data base and analytical models. But, the more important deficiency is that the potential decision makers and committee participants fail to recognize the interrelationships of the productivity opportunities to the overall supply picture; e.g., the necessity to do a marginal analysis so that it can be additive to the base line supply projections.

The second approach would be to integrate the development of investment opportunity data more into the overall resource planning analysis. For the national forests this should, and hopefully will, occur in NFMA planning. For the private land base, it could potentially occur through state forest resource planning. Ideally, state resource planners would take the forest survey data for their respective states and develop investment opportunity information which is an integral part of an overall state supply/demand analysis and which is compatible for use in regional or national analyses with models such as TAMM. Such an approach would assure credititiblity through local involvement, provide sensitivity to local conditions, and integrate the analysis into the overall supply/demand assessment.

In reality, most states probably do not have the resources or expertise to carry out such analyses in the near term. Therefore, we expect that any effort to update the productivity studies over the next 5 to 10 years will be a combination of both approaches and dependent on the capability and willingness of the states to implement such studies.

SUMMARY

In 1974, when the initial decisions were being made to do productivity studies, a lot of doubts existed. Admittedly the first effort had its problems and weaknesses. But the fact remains that a significant new data base was added to the overall analytical framework which allowed evaluation of the impacts of changes in forest policies and associated investment rates. Much work is underway or under consideration to improve on the initial effort. The ultimate objective must be a supply/demand analysis framework of which defining incremental opportunities and programs is an integral ongoing part and not a separate exercise.

METHODS OF ESTIMATING SUPPLIES FROM INTENSIFIED TIMBER MANAGEMENT

Richard N. Pierson

Abstract: Alternative methods for estimating potential long-run timber supplies from intensified timber management in the United States including MAI, TRAS adjustment, homogeneous stand type, and supply curve are defined and anlyzed. Suggestions are made for the application of these methods to international timber supply modeling.

INTRODUCTION

The increasing necessity to balance international timber supply and demand imbalances (Sedjo and Radcliffe 1980) through trade has resulted in renewed emphasis on understanding the potential of supplies from intensified forest management to meet global demands. Consistent with this trend has been the increasing investment in intensive forest management practices, such as plantation establishment and the complementary practices of tree improvement, spacing control and nutrition as well as their potential application to existing growing stock. The application of these practices have the biological potential for accelerating growth several times over growth on indigenous stands.

Economically, however, their application may be quite limited because of society's competition for scarce capital resources. Unfortunately most of the methods utilized for estimating potential timber supplies only partially recognize the economic context of scarce capital resources in their development. Subsequently the limitations of these procedures in an economic context or the potential integration of the methods in a more fully developed system, including demand and investment analysis components are emphasized.

Long-term in the context of these methods typically could represent the longest rotation-length employed in the geography analyzed. Geographically the methods presented are limited to those that have potential application to large scale, aggregate geographics, such as countries, states, provinces and/or homogeneous timber types.

METHODS

The following methods have been utilized in the United States for estimating the potential of long-run timber supplies from intensified forest management:

Mean Annual Increment Approach: This approach is the most straight forward of all the approaches utilized but because of its simplicity it lacks in sophistication. However, it does have flexibility for modification to make it more economically sophisticated. Basically the approach develops a potential timber supply projection through the extension of the mean annual growth estimate of intensively managed yields per unit area to an aggregate geographic area. Assumptions of long-term steady state forest regulation are implicit. Geographic stratification can be made in terms of timber type, ownership, site and allocation to varying levels of intensification.

This method has been popularized by the current Assistant Secretary of Agriculture for forestry affairs, John Crowell, through his estimates of the potential for National Forests in the United States to increase their output from their current levels in the vicinity of 12 billion board feet to around 34 billion board feet. In addition Robert Marty utilized this approach in his analysis for the President's Advisory Panel on Timber and the Environment (Seaton 1973).

The major problem in this approach for broad geographical applications are the economic reality of the inputs and the lack of specification of time period which becomes significant when there is a wide range of rotation lengths. Advantages includes its simplicity of calculation and relatively limited data requirements. Modifications of the allocations of acreage to homogeneous MAI yield classes could be accompanied by some investment analysis which would aid in the methods economic sophistication. The procedure does offer the opportunity for quickly estimating potential long-run supply and varying it by sensitivity analysis of the major input variables such as acreage and yield estimates. In addition it can provide a ready check on more complicated procedures and a basis of treatment acreage accountability necessary to reach calculated MAI potentials.

TRAS Approach: A modification of the basic TRAS (Larson and Goforth 1974) approach for projecting timber supplies on private lands in the United States was developed by Richard Barber at Oregon State University for incorporating alternative intensities of management (Barber 1980). Radial growth and basal area adjustments were made to target on the results of investment analysis of management alternatives developed by the National Forest Products Association Forest Industry Council (1980). Darius Adams and Richard Haynes projected nationally for eight regions supplies under intensified management utilizing TAMM (Adams and Haynes 1980) and the modified TRAS procedures developed by Barber.

Advantages of this method lie in its ability to provide estimates of supply over time. Problems lie in the growth projection procedures of TRAS which include only aggregate stand types for each region. Also the aggregate stand type prevents an accounting of treatment acreage. In addition changes in management intensity requires adjustments of mensurational data not commonly associated with intensive forest management yields. Finally the data requirements for integration of the TAMM econometric model on an international basis would be substantial.

Homogenous Acreage Base Models: Models of this type applied to large geographic areas have been developed, particularly in the Pacific Northwest. The most widely distributed model of this type has been the TREES model (Tedder, et al. 1980). The unique characteristic of this method which facilitates its ability to project timber supplies with intensified forest management is its classification and projection of the resource base in homogenous age, site and stocking categories. This enhances the ability to utilize conventional managed yield data collected on an acreage basis with similar inventory information.

In concept of growth projection it is very similar to models used by the USFS in management of National Forests. We also have found this type of an approach particularly useful in estimating future timber from the Weyerhaeuser Company's High Yield Forestry program of intensive management. Integration with regional demand analysis has also been undertaken (Rahm 1981).

Models of this type also provide time specific supply estimates and treatment acreage accounting. However, limitations exist in terms of international application. Specific age, site and stocking inventory data do not exist uniformly throughout the world. In addition, opportunities for matching intensively managed yields to existing inventory data are limiting. Furthermore, most applications of this procedure input prescribed forest management options without regard to an investment analysis of their economic contribution.

Supply Curve: Several approaches to developing a regional timber supply curve have been developed in the United States under slightly different procedures. Long-run supply curves for California (Vaux 1973), Georgia, (Montgomery, et al. 1976), Southeast (Robinson, et al. 1981) and the Pacific Northwest (Hyde 1980) have been developed focusing on particular issues of appropriate forest management base, intensity of management and price consequences. Essentially their methodology revolves around marginal investment analyses of alternative forest management levels applied to appropriate inventories and aggregated by MAI contribution into a price quantity supply function.

The major advantages of this approach is its relative ease of construction and the incorporation of investment analysis and price into the methodology. Problems exist, however, in terms of relative data availability and most seriously the lack of specification as to the time period to which the analysis applies. In this regard it is similar to the MAI approach.

CONCLUSION

Due to the data and time limitations associated with developing international long-run potential supplies from intensified timber management analysis should proceed from the simplest of approaches adding complexity and refinement as data and time become available. To the extent that most of the methods outlined build upon one another in terms of their data requirements and computational complexity very little would be lost by such an approach and results and insights could be gained in the process. Therefore, initial efforts should be placed on a MAI description of potential followed by supply curve development and finally if data and time permit a homogenous stand type analysis. In no case should a USFS TRAS base projection be considered for international application because of the problems outlined. Admixtures of other country's experience would undoubtedly be appropriate.

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APPLICATION OF OPTIMAL CONTROL THEORY TO ESTIMATE LONG-TERM SUPPLY OF TIMBER RESOURCES

by Kenneth S. Lyon and Roger A. Sedjo[1]

Abstract--This paper presents the application of a model for examining the potential long-term levels of timber harvest. The model incorporates features that allow it to deal with questions of the optimal rate of drawdown of existing old growth stands, as well as to project the output levels after the transition has been completed and a steady state ensues. An optimal control theory algorithm is used to solve the problem. The paper discusses plans for applying the model broadly to examine global potential future production.

Additional Keywords: optimal control theory, long-term timber production projections, old growth inventories, regeneration, forest plantations, timber harvest scheduling.

INTRODUCTION

One of the more intractable problems in forest economics is the question of the long run supply or supply potential of forest resources. The forest resource, in the short and intermediate term, has many features similar to that of a nonrenewable resource. Specifically, the resource is relatively fixed and utilization of the resource results in a mining type activity, i.e., the depletion of a "fixed stock." One of the economic questions of the theory of mining is the optimal rate at which the resource is utilized. However, unlike true nonrenewable resources, forests have a renewable feature. Even without artificial regeneration, the forest will generally regenerate itself naturally if the land is not utilized for other purposes. Thus the natural forest has a certain rate of natural regeneration and replenishment. This process can be accelerated and enhanced through the intervention of man. Man can undertake a variety of conscious investment and management activities that will affect the rate of growth and quality of the resource. Also, man can consciously intervene to control regeneration with respect to the speed of regeneration, the species, and geographic location. By controlling the species and location, man is in a position to choose biologically superior species and sites.

1This paper was prepared for the North American Conference on Forest Sector Models held at Williamsburg, Virginia, December 2-4, 1981 as part of the Forest Economics and Policy Program (FEPP) of Resources for the Future (RFF). Kenneth Lyon is an Associate Professor of Economics at Utah State University. Roger Sedjo is Senior Fellow and Director, FEPP.

In the short run the question of supply relates largely to the question of the rate at which the existing stock is drawn down. However, in the long run, the stock is a variable and subject to alteration. Thus the long-run supply involves both the rate at which the stock is increased as well as the rate at which reforestation and afforestation are taking place, and the extent to which management can alter the biological growth rates. In this context, short-run supply decisions relate not only to the size of the existing stock, but also to expectations regarding the rate at which that stock will be changing through time.

The problem of long-run supply is complex. First, the world's woodbasket is filled from a variety of supply sources (Sedjo, 1981). These include natural old growth forests, naturally regrown forests, artificially regenerated forests created for protection or recreational purposes and, finally, industrial plantation forests. Furthermore, the contribution of the various types of forests to total supply is systematically changing over time. Most notably, the role of "old growth" forests is declining, while that of industrial plantations is increasing. In addition, the land area in commercially usable forests is changing. While some lands are being taken out of forests and used for agricultural and other nonforest uses, simultaneously other lands are being converted into forest use. For example, while in some regions forest lands are converted to other uses, many discarded agricultural lands of the U.S. South have naturally reverted to forest and industrial forest plantations are currently being established on nonforest lands in many regions of the world.

The extent to which these various types of forests contribute to the supply of industrial wood is largely related to economic considerations. The location of the resource vis-a-vis world markets, its general accessibility, the costs of harvest, wood merchantibility, and so forth, largely determine the extent to which a forest of any type will be utilized for industrial wood. Therefore, one might expect to find that certain old growth forests will be entirely harvested while other old growth forests may be only minimally disturbed. In some regions artificial regeneration may make economic sense, while other regions may rely upon the less rapid and lower quality natural forest regeneration. Afforestation may make sense on some lands that were not previously forestlands. Finally, in still other regions, alternative uses of the land may preclude further forest use. Thus, at a point in time the various forests of a large country or of the world as a whole may be in different states of exploitation and development and may be making very different contributions to aggregate timber supply.

A further complication arises. As noted above, the contribution of the various types of forests to total supply is changing systematically over time as the "old growth" inventories are being depleted and as regrowth and plantation forests provide a larger portion of total supply. We have discussed the features and implications of this transition elsewhere, likening it to the earlier transitions from gathering to cropping and from hunting to livestock raising (Sedjo, 1981a). The implication of this transition is that the composition of the long-run supply curve will be changing as the transition progresses. Eventually, one would expect the transition to be complete and a type of steady state forest situation to ensue (Lyon, 1981). The steady state forest would consist of industrial forest plantations, a portion of naturally regenerated forests that are harvested on a more or less continuous basis, and finally a residual of old growth forests that are not utilized due to their inaccessibility, distance from markets, or lack of merchantability.

A final complication is the outgrowth of the relation between the future supply of timber and current consumption. To the extent that changes in current (and subsequent) consumption influence the remaining timber inventory levels and the planting levels, they influence future supply. Thus, the future supply schedule is related to the preceding time path of consumption.

As complicated as it may be, the importance of long-run estimates of supply, supply potential, and supply response should not be minimized. Concerns over the availability of future timber supplies are raised not only within the United States, but also within a global context. Given the long gestation of trees, some notion of the future availability and some expectation of future prices are critical components of any decision, private or public, to invest in regeneration and timber management.

The Approach

The major tool to be used to empirically examine the long-term timber supply curve or supply response[1] is an optimal control theory type model. Such a model will allow for the estimation and projection of economic rates of harvest from existing forests--old growth, natural secondary growth, and manmade. In addition, tree-growing production functions will be incorporated into the model to provide projections of regeneration, growth, and ultimately harvest for each class of forest lands.

It should be noted that while some aspects of the proposed approach are similar to techniques commonly used in timber harvest scheduling models (Johnson and Scheurman, 1977, and Walker, 1971), there are important differences in both technique and application. Timber harvesting models are commonly used to assist in the management of rather small units of forest. Features that are commonly found in timber harvest scheduling models include a linear programming approach and the assumption of the price of stumpage as fixed and exogenously determined.

This study, by contrast, uses the more efficient optimal control theory approach (Butrovskii, 1963 and Abadie, 1970). Optimal control theory has been recognized as offering substantial promise for application to forestry problems. It is generally recognized as being superior to other techniques, e.g., linear or separable programming, in terms of efficient use of computer time. In addition, it readily lends itself to dealing in an efficient manner with downward sloping demand curves.

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[1]This terminology is used since the curve estimated has some characteristics that differ from the usual Marshallian supply curve.

Despite the promise of optimal control theory for dealing with forestry problems, this promise has not been realized.

However, the problem being addressed in this study is ideally suited to investigation by optimal control theory techniques, and the approach and preliminary results presented in this paper demonstrate, we believe, the usefulness of such a technique.

Besides introducing an optimal control theory approach, this project addresses a very different set of questions than do timber harvest scheduling models. The model is not designed to be a management aid for a particular forest. Rather, it is a tool for investigating the aggregate long-run economic potential for timber production from the major forests of the globe. As such, the approach necessarily takes a global view. Large regions of the world will be introduced as one or two land classes. The model will incorporate most or all of the major world regions. Regional tree-growing production functions will be introduced, together with an aggregate downward sloping global demand curve. Locational considerations will be incorporated with the introduction of transport costs to major markets.

The completed system will allow for the long-run projection of output and prices of timber. Modification of the demand function will generate different time paths of output and prices. A comparison of the various time paths will allow estimates to be made of long-term harvest supply response. In principle, the model can handle an unlimited number of land classes. By adding appropriate regions of the globe as different land casses, all of the relevant forest producing regions of the globe can be incorporated into the model.

It should be noted that this approach will examine the economic potential of long-run supply response potential. The study abstracts from such important real world considerations as ownership patterns, institutional constraints that generate non-economic responses to market signals, vicissitudes in incentive and tax policies, and so forth. The intent of this study is to focus upon basic long-term economic and biological fundamentals. After the basic economic projections have been completed, it will be possible to introduce noneconomic factors and to estimate the extent to which these factors modified the initial economic projections.

The Study's Relation to Existing Work

The proposed study addresses a concern often raised: What is the long-term supply response potential of timber production to economic incentives? A number of attempts have been made to look at this question both regionally and globally.

In an FAO study (FAO, n.d.) a series of long-term (to the year 2000) supply and demand projections were made relying principally upon extrapolating existing trends and introducing modest ad hoc adjustments. In another study the U.S. Forest Service developed its Timber Assessment Market Model (Adams and Haynes, 1980) which made fifty-year projections of U.S. stumpage demand and supply. The approach for estimating long-run supply relied on the estimation of empirical short-run supply curves which were shifted through time. The shifts were a function of autonomous changes in forest inventories. A third approach was developed by Clawson and applied by Hyde (1980) to the Pacific Northwest Region of the United States. Hyde estimated long-run supply curves based upon the selection of a management regime that maximized the present net worth of stumpage returns. Hyde's approach, however, ignored the existing timber inventories and thus provided projections for the period after the transition to forest plantations had been completed. In addition, Hyde's approach assumed that the region was a price taker. Thus, stumpage prices were determined exogenously throughout his study.

The proposed study will allow investigation of the question of long-term supply within an environment where an explicit transition from old growth forest to plantation forestry is underway. Supply projections will be made for both periods during the transition as well as for the subsequent steady state. In addition, since the regions being examined are relatively large, stumpage prices will be determined endogenously.

The proposed study can be viewed as integrating a timber harvest scheduling approach (not typically used for making region-wide supply projections) with a Clawson-Hyde type analysis of the economics of tree growing in the long-run. In this manner, projections of regional long-term supply can be obtained both for the period of transition and for the steady state.

Using this approach the proposed study will provide a time profile for timber production through the transition and into the steady state, a time profile for stumpage prices through the transition and into the steady state, and estimates of long-term timber supply response by varying the demand conditions which will in turn create alternative time profiles that can be used to estimate supply response. The study will be international in scope, analyzing several regions and then relating these analyses.

The proposed study will provide unique contributions in the form of a) an improvement in the state of the art of long-term forest production supply projections (using optimal control theory) that recognizes both the effects of existing inventories and the ability to create new inventories; b) the development of superior long-term economic timber supply projections which explicitly recognize the effect of the transition supply; c) the estimation of long-run steady-state timber supply (harvest response) curves; and d) the integration of a number of regional forests to provide insights into the overall distribution of international forest resource supply potential through the transition period and into the steady state.

The Model

This section describes an algorithm for numerically solving for the optimal time path of several control variables in a timber supply-demand model. The algorithm is an intermediate step in our search for an algorithm to solve relatively complex problems. We began our search with a simple problem and have now increased the complexity by adding variables to be controlled. The current computer program is able to solve for the time path of optimal harvest levels and regeneration input expenditures on two different qualities of forest land. (Increasing the number of land qualities requires no new theory, just programming steps.)

We are structuring the problem as a discrete time optimal control problem (DTOCP) which is used to identify the equalities and inequalities that will exist at the optimum. This information is also used to identify the direction of change from an existing time path of the control variables to a superior time path. The literature calls this the generalized reduced gradient method of solving optimality problems.

General Description

The objective function for the model is the discounted present value of the time stream of net surplus (consumers' plus producers'). This function is maximized subject to the initial conditions and the laws of motion for the system. The initial conditions include such items as acres of forest by age and land class. They also include the magnitude of a composite regeneration input by each of the acres. This composite input is the present value of all planting and silvicultural operations.

The laws of motion for the system are the rules that govern the system. These include the rules that make i, say 10, year old trees in year j, say 5, which were regenerated using Z dollars, say $50, of the regeneration input per acre, i + 11, year old trees in year j + 1, 6, which were regenerated using Z dollars, $50, of the regeneration input per acre. The current version of the model regenerates each harvested acre in the year that it is harvested; thus these acres become in the next year acres that were regenerated one year ago using a specific amount of the regneration input. These rules, therefore, take into account the rolling of acres of trees and the regeneration input from one year to the next and take into account the harvesting and regeneration of acres of trees.

The optimization algorithm first solves for the optimal level of the regeneration input and rotation period by land class for the stationary state. The stationary state is where the system does the same thing year after year unless it is disturbed by some outside force. Then the program and the operator interact to find using interpolation techniques a time path for the control variables and consequently for the state variables from the intial conditions to the stationary state over a period of time, say 150 years. The control variables are the harvest levels (rotation period) and the magnitude of the regeneration input in each year by land class. The state variables are the acres of trees by age and land class and the associated regeneration input for each of these acres.

Next the program calculates the direction of maximum ascent of the present value of the net surplus hill and takes a step in that direction. It calculates the length of the step through an iterative process. This step puts the control variables on a new time path. Acres harvested and the regeneration input in each year may have been adjusted. This procedure is repeated until the operator signals it to stop.

The role of discrete optimal control theory is the identification of the equations and inequalities to be solved to identify the stationary state and to identify the equations to be solved to identify the direction of steepest ascent.

Equations

We now identify the functions and equations of the model. This identifies the types of cost functions, demand functions, and production functions that we are using, and it identifies the way we are writing the laws of motion. It also identifies what would have to be done to alter the model to fit a specific region. To simplify the discussion, the model will be developed, manipulated, and discussed using only one land class. Then, the vectors and matrices will be redefined and the work already discussed used to identify the relationships for the model with more than one land class.

In developing and manipulating the model we use vectors and matrices and their algebra. The literature on the DTOCP uses almost exclusively this algebra because of its relative advantage. The forestry problem is different enough from the usual DTOCP that the matrix notation and algebra loses some of this advantage; however, it is still superior to using the summation notation.

The objective of the DTOCP is the maximization of the present value of net surplus subject to a set of constraints. Net surplus is defined as consumers' plus producers' surplus. The surplus in year j can be written

$$s_j = \int_0^{Q_j} d(\kappa)d\kappa - C_j \quad (j = 0, 1, \ldots, J - 1)$$

where Q_j is the quantity (volume in, say, cubic feet) of timber consumed in year j, $d(Q_j)$ is the inverse form of the demand function, and C_j is total costs in year j. The total costs are the sum of regeneration costs and harvesting costs (CH). Thus

$$C_j = CR_j + CH_j \quad (j = 0, \ldots, J - 1)$$

Define x_j to a vector of acres of trees in each age group in year j. x_j is called a state vector and its elements are defined x_{ij} and indicate the acres of trees in year j that were regenerated i years ago. As an example, x_{59} = 20 means that in year 4 there were 20 acres of trees regenerated; thus in year 9 they were regenerated 5 years ago. To simplify the discussion we call x_{ij} the acres in age group i in year j. We note, however, that trees regenerated i years ago may not be i years old. At one level of the regeneration input they may be i - 2 years old and at a lower level of this input they may be i + 4 years old. The length of the x vector is I with I equal to or greater than one plus the longest rotation period in any year. In addition, we let X_j be a diagonal matrix of the elements of x_j.

The control variable for harvesting timber is u_{ij} and denotes the portion of age group i harvested in year j. The vector of these is denoted u_j and is called a control vector.

The commercial volume of timber per acre in year j in a stand regenerated i years ago depends upon i and upon the magnitude of the regeneration input used i years ago (Z_{ij}). The Z_{ij} are called state variables and are used to associate the acres of trees regenerated i years ago (x_{ij}) with the appropriate level of the regeneration input, the one used i years ago (Z_{ij}). We denote this commercial volume

$$q_{ij} = f(i, z_{ij}) \qquad (1)$$

With these definitions we can write the equation for volume of timber consumed in year j as

$$Q_j = u_j X_j q_j = \sum_{j=1}^{I} u_{ij} x_{ij} q_{ij} \qquad (2)$$

The regeneration cost in year j is given by

$$CR_j = u_j' x_j w_j \qquad (3)$$

where w_j is the per acre regeneration expenditures in year j. w_j is a control variable and is a scalar. The product $u_j x_j$ gives the acres harvested and regenerated in year j.

We use a harvesting cost function that has a fixed entry cost per acre and a variable cost that depends upon the total volume harvested. This is written

$$CH_j = u_j' x_j c^1 + c^2(Q_j) \qquad (4)$$

where c^1 is the fixed entry cost per acre and $c^2(.)$ is a function with positive first derivative and negative second derivative.

Using these definitions we write the objective function, the present value of the net surplus stream, as

$$S_0(x_0,z_0,u,w) = s_0 + \rho s_1 + \dots + \rho^{J-1}s_{J-1} + \rho^N S_j^*(x_j,z_j) \quad (5)$$

where ρ is the discount factor, exp(-r), with r the market rate of interest, u is any admissible set of control vectors, $u_0, u_1, \dots, u_{j-1}$, w is any set of admissable control scalars $w_0, w_1, \dots, w_{j-1}$, and $S_j^*(.)$ the optimal terminal value function. The notation $S_0(x_0,z_0,u,w)$ indicates that the time zero present value of the net surplus stream depends upon the starting point (initial conditions, x_0, z_0) and the time path for the control variables ($u = \{u_0, u_1, \dots, u_{j-1}\}$ and $w = \{w_0, w_1, \dots, w_{j-1}\}$). The super asterisk is used to indicate optimal quantities; thus the constrained solution at time zero would be denoted $S_0^*(x_0,z_0)$. The symbols u and w were not included because they are not variable in S_0^* as they are in equation (5). The term $S_j^*(x_j,z_j)$ is a terminal value function and can b viewed as S_0^* was.

Equation (5) is maximized subject to a set of constraints. The constraints are those on the value of the control variables and the laws motion of the system. The portions of acres harvested are constrained to be nonnegative and less than or equal to one, and the regeneration inputs are constrained to be non-negative

$$0 \leqq u_j \leqq 1 \quad (j = 0, 1, \dots, j-1) \quad (6a)$$

$$0 \leqq w_j \quad (j = 0, 1, \dots, j-1) \quad (6b)$$

where 1 is a vector of ones and the vector inequality holds for each element. The laws of motion for the system are given by

$$x_{j+1} = (A + BU_j)x_j \quad (j = 0, 1, \dots, J-1) \quad (7a)$$

$$z_{j+1} = Az_j + w_j e \quad (j = 0, 1, \dots, J-1) \quad (7b)$$

where A, B and U are I-square matrices, U_j is a diagonal matrix using the elements of u_j, and e is an I-vector.

The product Ax_j moves, rolls, x_{ij} to $x_{i+1,j+1}$. Each year each age group ages one year. The product BU_{jx_j} subtracts from the rolled quantities the acres harvested and places them in the one year old category (newly regenerated category). These can be expressed as

$$x_{1,j+1} = u_j x_j \tag{8a}$$

$$x_{i+1,j+1} = x_{ij} - u_{ij} x_{ij} \quad (i = 1,\ 2, \ldots,\ I = 1) \tag{8b}$$

In the law of motion for z, the product Az_j moves, rolls, z_{ij} to $z_{i+1,j+1}$. This parallel rolling of x and z keeps the regenerated acres and the level of their regeneration input in the same relative position in their respective state vectors. The scalar product $w_j e$ places w_j in location $z_{1,j+1}$. Thus

$$z_{1,j+1} = w_j \tag{9a}$$

$$z_{i+1,j+1} = z_{i,j} \qquad (i = 1,\ 2, \ldots,\ I - 1) \tag{9b}$$

To achieve this A, B and e are defined as

$$A = \begin{bmatrix} 0 & 0 & 0 & 0 & . & . & . & 0 \\ 1 & 0 & 0 & 0 & . & . & . & 0 \\ 0 & 1 & 0 & 0 & . & . & . & 0 \\ 0 & 0 & 1 & 0 & . & . & . & 0 \\ 0 & 0 & 0 & 1 & . & . & . & 0 \\ . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix} \qquad e = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \\ . \\ . \\ . \\ 0 \end{bmatrix}$$

$$B = \begin{bmatrix} 1 & 1 & 1 & 1 & . & . & . & 1 \\ -1 & 0 & 0 & 0 & . & . & . & 0 \\ 0 & -1 & 0 & 0 & . & . & . & 0 \\ 0 & 0 & -1 & 0 & . & . & . & 0 \\ 0 & 0 & 0 & -1 & . & . & . & 0 \\ . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . \\ 0 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \end{bmatrix}$$

The Solution Technique

The discrete time optimal control literature contains extensive discussions of the standard, Hamiltonian, technique for solving these problems and it contains many theorems concerning the Hamiltonian and the costate variables. In addition, this problem can be molded to fit a few of these theorems; however, it is more instructive to state the Hamiltonian theorem for this specific problem and to prove the theorem using a relatively simple technique from the DTOC literature. This procedure tailors the results and identifies the specific relationsips to be used to numerically solve the problem. The solution technique is detailed in another paper (Lyon, 1981a).

An Application

In this section we report on the results of the application of the model to a set of hypothetical data. This approach was used to determine whether the model would generate sensible solutions (time paths) and to give the model users a better sense of the types of output that can be generated by this approach. A two land-class case is examined; however, this can be expanded to handle, in principle, an unlimited number of land classes.

Figure 1 presents a natural true growth yield curve in volume by land class. The higher curve represents the higher yield land class.

Figure 2 presents the yield curve on class I land for three different levels of management imput--no input, 20 units of input per acre, and 40 units of input per acre.

Figure 3 examines the harvest volume over time by land class for the low demand scenario. It will be noted that the old growth inventories on the higher class lands are harvested more rapidly initially and then the harvest is shifted to the old growth inventories on the lower sites. This leads to two different harvest cycles that eventually converge in the steady state.

Figure 4 presents the projected stumpage price over time. Initially, given the availability of large volumes of "old growth," the price is relatively low. As the old growth inventories are depleted the price rises, reaching a maximum during the transition where the old growth inventories have essentially been depleted and something less than the steady state volumes are available from regeneration. However, this situation soon is past, as price declines to its long-run equilibrium as volumes reach their steady state levels.

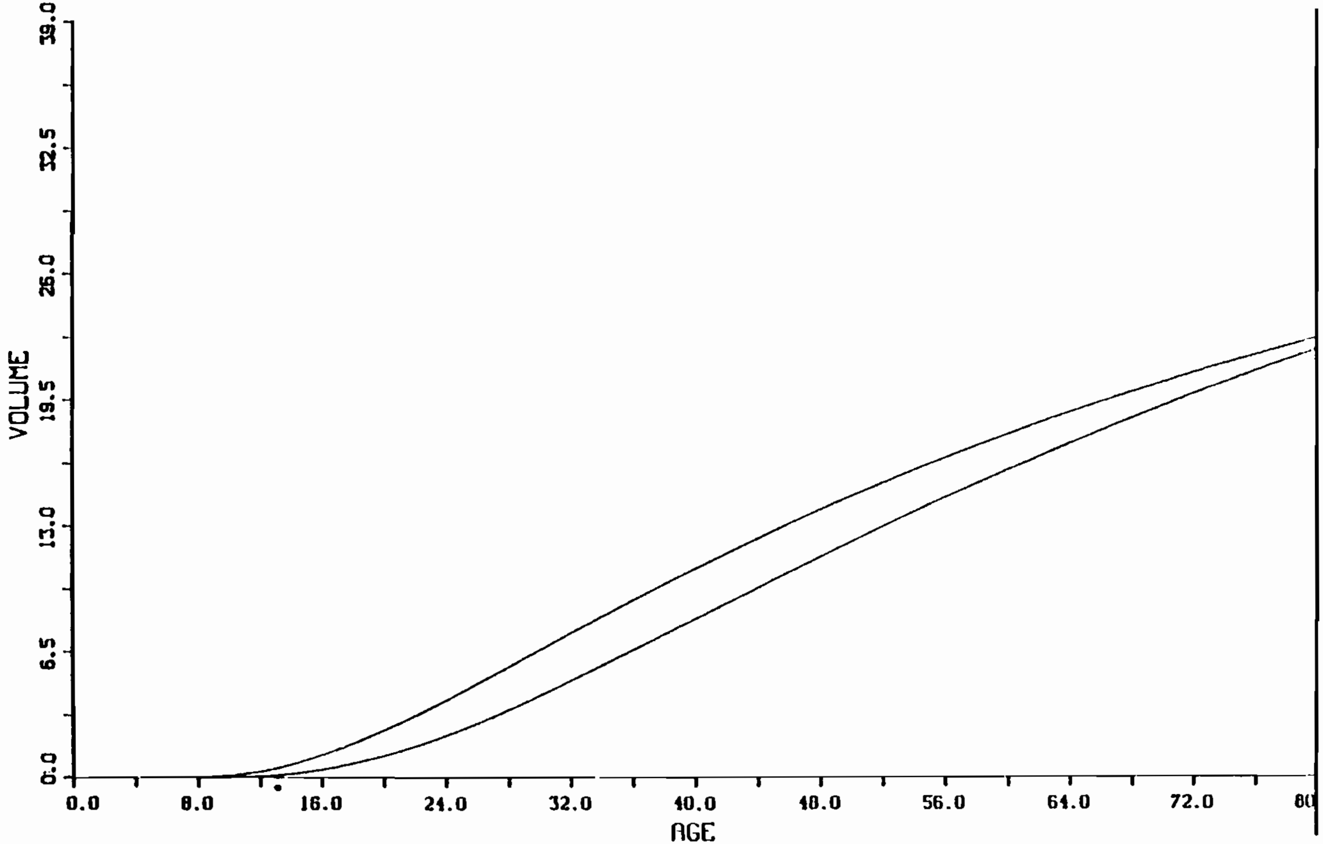

FIGURE 1 NATURAL TREE GROWTH BY LAND USE.

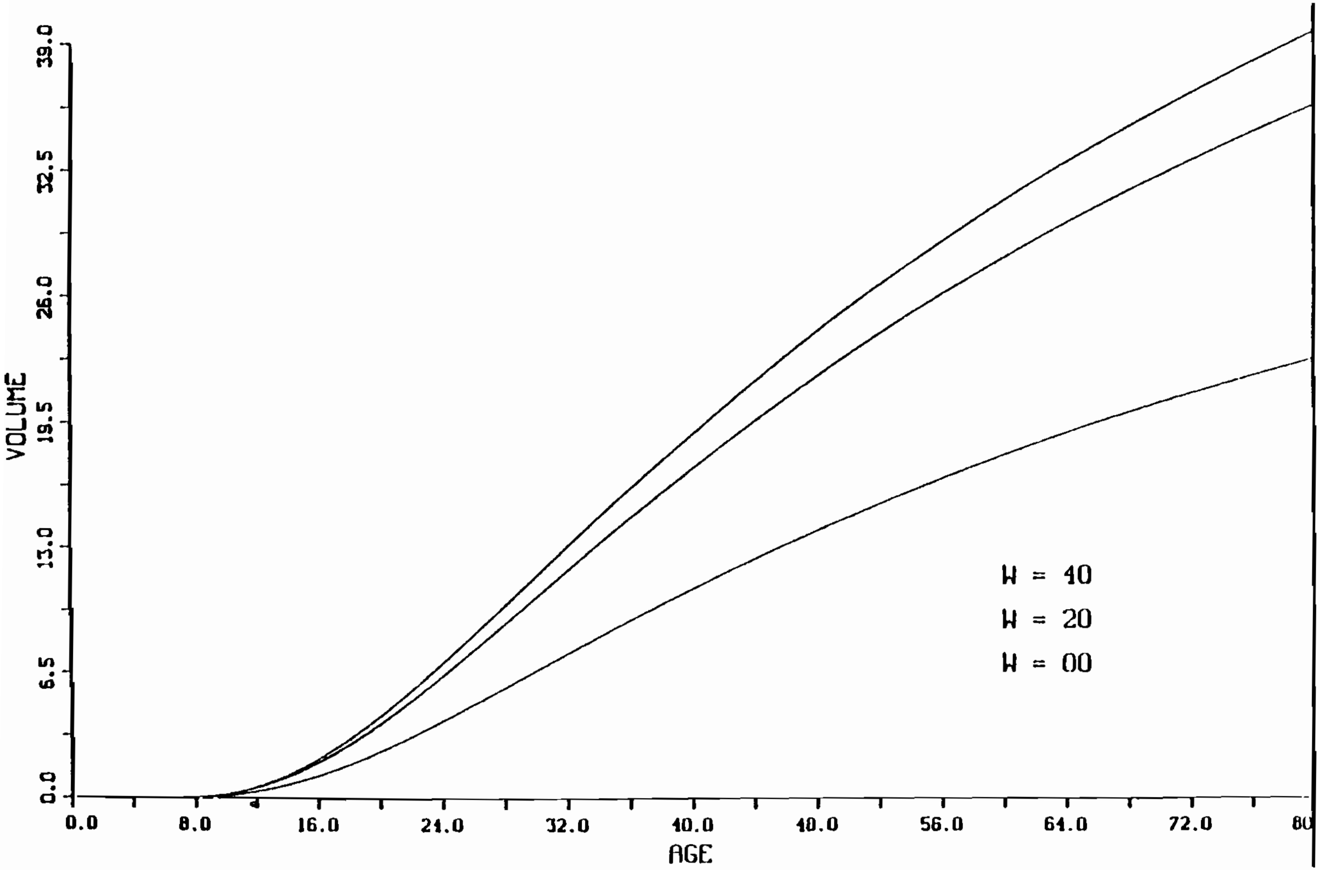

FIGURE 2 TREE GROWTH : LAND CLASS 1.

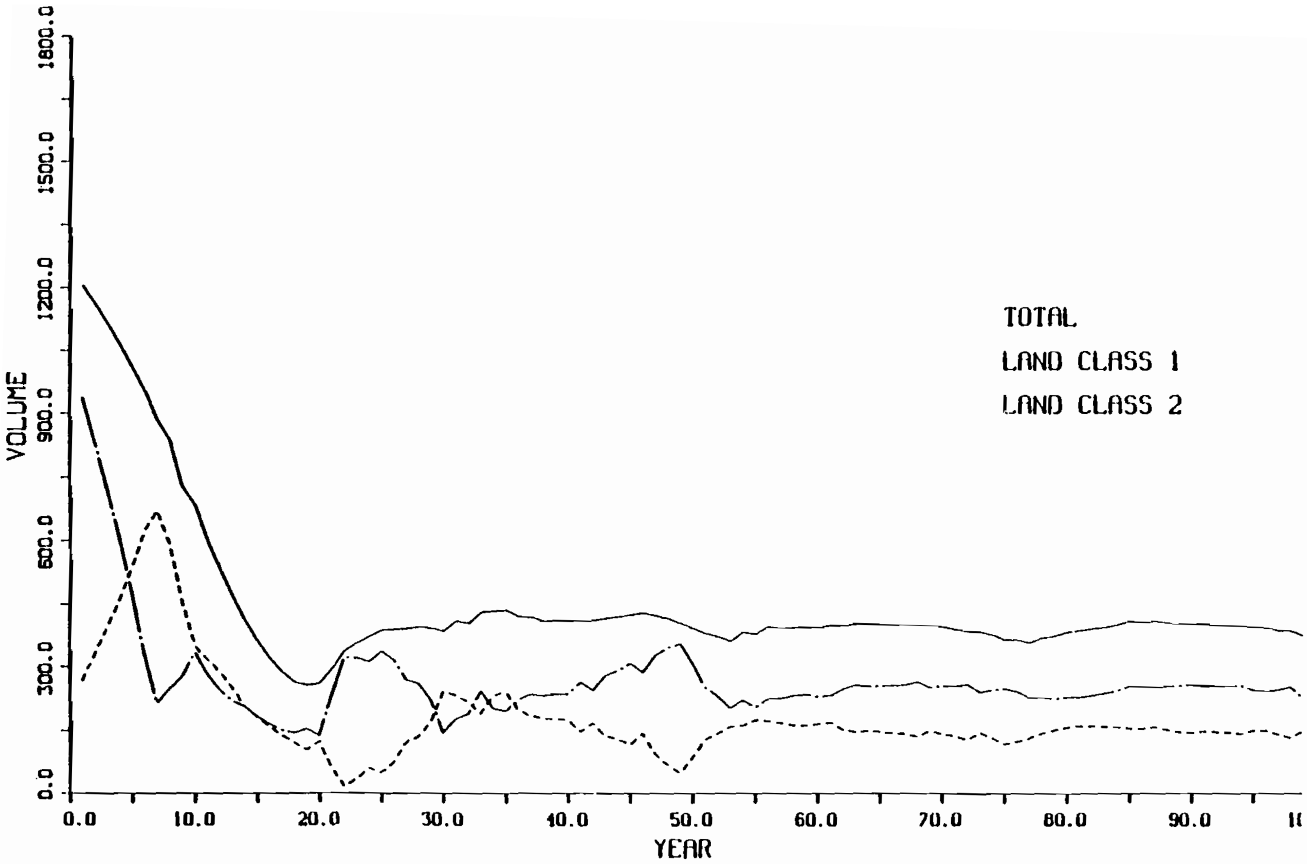

FIGURE 3 VOLUME OVER TIME.

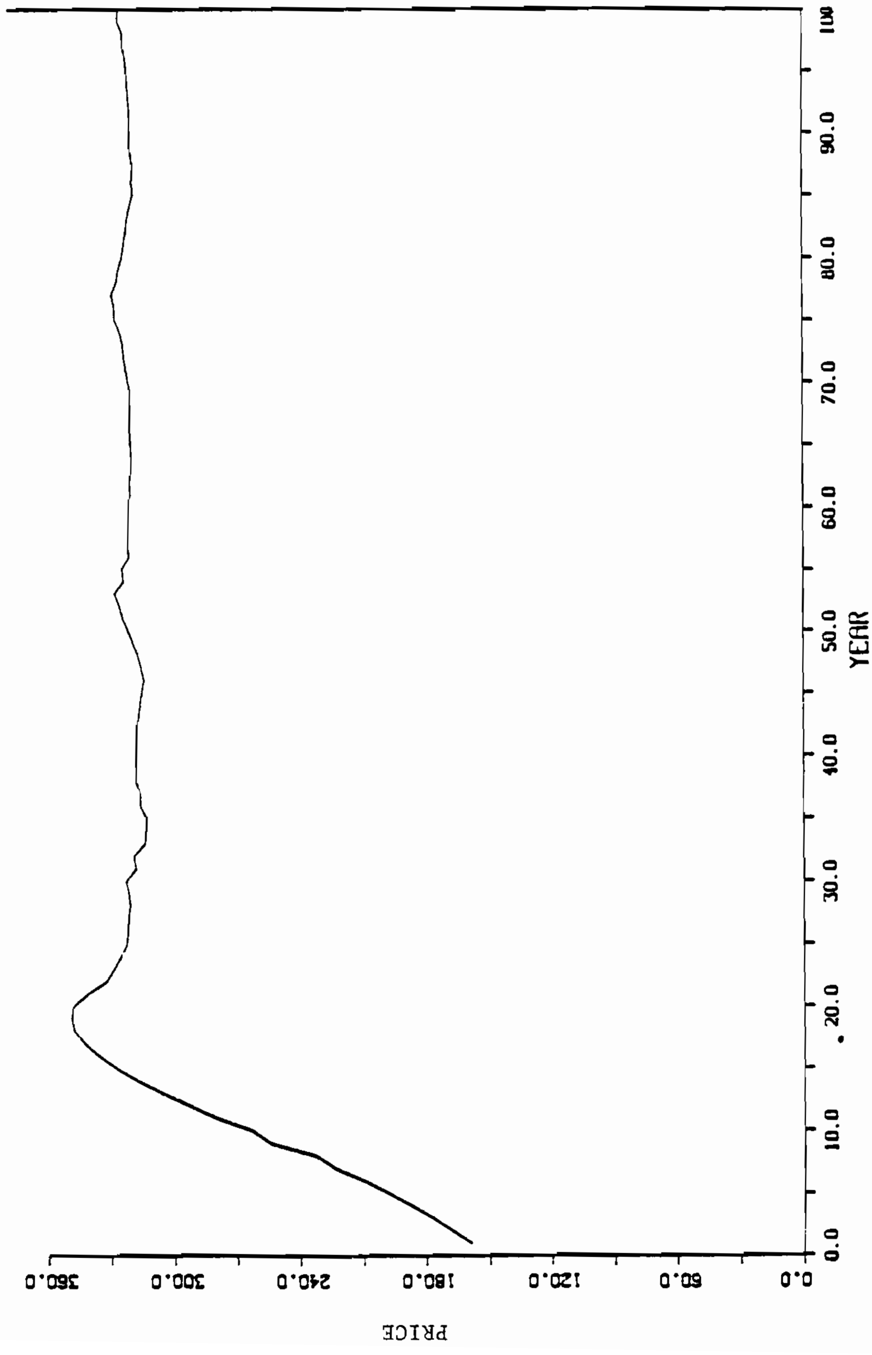

FIGURE 4 PRICE OVER TIME.

Concluding Summary

The preceding discussion presented a simple variant of the timber supply model. Using hypothetical data the time paths of prices and volumes were generated. It can be seen, however, that the results are sensible. A variant of the model can be applied to examine any region where the data are available and the demand curve adequately captures the conditions of the region, including imports and exports. The analysis can be expanded to incorporate the "global region" by introducing each of the regions as a separate land class. In addition, a transport cost function relating the supply factor to its major market captures the spatial features of the system.

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Optimization Models of Timber Supply: a comment on "Application of Optimal Control Theory to Estimate Long-Term Supply of Timber Resources" by Ken Lyon and Roger Sedjo

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Abstract. The operation of a competitive market can be simulated by solving a mathematical program which maximizes consumer plus producer surplus subject to an appropriate set of technological constraints. Only recently has this approach been applied to the forest sector; Ken Lyons and Roger Sedjo have improved our theoretical understanding of timber markets from precisely this vantage.

INTRODUCTION

These comments on their paper are in the three parts. First, the major contributions of the paper can be highlighted by placing their analysis in the context of the extant literature. Second, a few other studies have adopted the maximization of net surplus approach to market modelling, and it is useful to compare the Lyon-Sedjo approach with one such application: the Pacific Northwest Regional Commission Forest Policy Project (Bruner and Hagenstein 1981). Finally, because of the strong intertemporal linkages in timber supply, the level of demand in any one period affects supply in all periods. That the existing Lyon-Sedjo algorithm cannot account for this important facet of timber markets limits its utility for practical application to price or output forecasting.

Optimization Models of Timber Supply

Three levels of timber supply can be identified: the individual acre, the forest property and the forest region. On the individual acre, stumpage price is constant with respect to output and the key economic issues are the optimal level of management intensity and rotation age (alternatively, the optimal inventory). Foresters associate this theory with Faustman; modern treatments are given by Samuelson (1976) and Commoli (1980).

Typically individual acres are not managed in isolation, nor do the economic forces which influence management operate on individual acres alone. Consequently important supply issues begin at the property level, and the question of harvest scheduling arises. Demand is typically taken to be perfectly elastic (although in some cases maximization of monopoly revenue is the objective), and the problem is to find the optimal sequence of harvest levels by age class, site class, perhaps by other stand identifiers. At this level, the analysis recognizes the age structure of the existing timber inventory, and constraints describe the growth of the inventory from one period to the next as a function of the age structure. Sometimes other constraints are added, forcing harvest levels never to decrease, for example, or constraining

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certain ancilliary outputs of timber harvest (e.g. sediment). The so-called model II LP's (Johnson and Schuerman, 1977; the formulation given is incorrect, see Dykstra, 1982 for the correction) are one example. ECHO (Walker, 1975) was used in the Timber Harvest Issues Study (USFS, 1976) with a nonlinear objective representing the maximization Forest Service monopoly revenues. The FORPLAN model (Johnson, Jones and Kent, 1980) used by the U.S. Forest Service is perhaps the most elaborate of this type of model yet devised.

At the regional level, models of timber inventory development take on the full characteristics usually associated with the concept of economic supply. On one hand, there is a rich history of long run supply models commonly traced to Vaux's (1954) analysis of the sugar pine resource in California, and subsequently developed the south by Robinson (e.g. 1980) and for the Douglas fir region by the Forest Service (1963), and Hyde (1980). Jackson (1980) gives the definitive theoretical treatment of this approach. Like the individual acre analysis, these models determine the optimal management intensity and rotation age for a specificed price. Then the level of supply associated with that price is the mean annual increment per acre multiplied by the number of acres in production. Typically several site classes are distinguished, and sometimes several forest types are also identified. The price level is varied and the calculation repeated to map out the entire supply curve. These models implicitly assume that the forest is fully regulated and thereby ignore the age structure of the existing inventory. That the economically efficient forest under any particular demand scenario is fully regulated remains to be proven (with stationary demand I suspect it is).

As a consequence of this assumption, the interesting question of the approach to the equilibrium is ignored. Supply behavior in transition is of vital interest because the transition period typically approximates a rotation age, so the long run models describe a situation which is 30 to 50 years away, at best. Models of the transition which maximize net surplus or some measure like it have been built, but to date use continuous time and an "ageless" inventory. (e.g. Anderson 1976). Optimal management intensity is not treated in these models, but they do anticipate the time path of timber prices through the transition into the steady-state equilibrium of long run supply (see also Lyon, 1981).

Here is where the major contribution of the Lyon and Sedjo paper lies: it provides an explicit theory of the transition to the steady state equilibrium with a timber inventory possessing age classes and with the possibility of altering management intensity as a consequence of anticipated future prices. Their model shows the development of prices and harvest level with stationary demand (it would be a small effort to solve the model with demand varying over time in a known, exogenous way). The forest comes to a steady state with constant harvest over time. Using this model, one could test the hypothesis that the equilibrium forest is fully regulated.

As a consequence of this approach, near term harvest levels are part of the transition to the long run steady state. Characterizing short run supply in this manner implicityly assumes fully informed owners and perfectly competitive markets. Neither condition may hold for stumpage markets. Adams and Haynes (1980) took an alternative approach and estimated short term supply equations from historical time series on harvest level, price and inventory. That method avoids any explicit behavioral assumptions concerning timber supply, but over the long run, inventory developes as a sequence of steps from short run equilibrium to short run equilibrium without any notion of intertemporal equilibrium imposed between periods. Additional basic research on the behavioral determinants of short and long run timber supply behavior is needed.

Comparison with TREES

Alternate methodologies are available for calculating the harvest schedule which maximizes net surplus. One; the so-called TREES model (Tedder, et al.), uses a heuristic to solve the problem. Recently this model was implemented for the three-state Pacific Northwest region (Rahm, 1981). Because TREES and the Lyon-Sedjo algorithms solve essentially the same problem, it is useful to compare them.

In the first place, the TREES model can recognize considerable land classification detail. For example, almost 1700 land classes were used in the Forest Policy Project implementation of TREES, representing owner types, site quality, location and forest type. The heuristic used to solve the model is efficient in handling this level of detail, but the performance of the Lyon-Sedjo model in this regard is unknown. Because it uses more a priori information concerning the nature of the optiming it conceivably is faster.

Second, although TREES describes land classes in considerable detail, present net surplus maximization routine differentiates lands only on the basis of stand age. Site class, for example, is explicitly ignored in the harvest decision. Because site quality is a critical determinant of optimal rotation age, management intensity and land value this limitation may seriously undermine the precision of the TREES model when used to simulate the operation of a competitive stumpage market. The Lyon-Sedjo algorithm operates under no similar restriction.

Third, the current implementation of TREES assumes linear marginal cost and demand equations. The Lyon-Sedjo model can handle more general cost and demand structure.

Finally, unlike the Lyon-Sedjo approach, TREES does not compute the optimal level of management intensity endogenously. In general one could assume a level of management intensity for each period, solve for timber prices over time and them recompute the optimal level of management intensity. As in the TAMM analysis (Admas and Haynes, 1981), this process could be iterated until some desired convergence in prices between iterations is achieved. In the Forest Policy Project implementation of TREES this procedure was followed for the first period alone. It turned out that the level of management intensity initially assumed was optimal so no iteration was required.

Demand Considerations

In the Lyon-Sedjo model the demand curve is used only to identify the supply curve, so one might presume the character of the demand structure was unimportant to the analysis. However, timber demand is derived from lumber demand, so timber demand depends, in part, on lumber mill capacity. Mill capacity in any region depends on the profitibility of that region vis-a-vis competitive regions. In turn, profitibility depends on stumpage prices. Consequently demand shifts endogenously over time contingent on previous (and, in theory, future) period equilibrium prices in timber markets. Capturing this interaction is quite difficult because of the necessity to specify a model of capacity adjustment. In the Forest Project, the Data Resources, Inc. simulation system was used to model shifts in capacity in response to timber price levels and trends (Cardellichio and Veltkamp, 1981). A series of timber demand curves were constructed, where each curve was conditional on the previous period's equilibrium price. The supply model was then solved iteratively until a consistent set of demand curves were used in all periods.

From a supply perspective, the problem is of more that theoretical interest because of demand-related allowable cut effects. The optimal harvest schedule is defined by a series of marginal conditions which describe the equilibrium path of prices through time. If future demand shifts, harvest in all periods will shift to maintain the equilibrium conditions between periods. Thus if demand in a future period shifts out, future prices will rise. The forces of intertemporal equilibrium will shift harvest from the early periods into the later periods. This will have the effect of reducing early period harvests and raising early period prices.

Summary

The model presented by Lyon and Sedjo ties up some important loose ends in the theory of forest economics related to the transition between the existing inventory and the long run level of supply. This is an important contribution and is the main value of the paper.

Primarily because of limitations in the demand structure, the model is not a practical tool for supply or price forecasting. Further, before adopting the algorithm, it would be valuable to test the relative efficiency against existing heuristics such as TREES which solve similar problems.

Finally, timber supply depends not only on timber inventory level and management intensity, but also on the land base devoted to timber production. The economic level of land to hold in timber depends on the value of the land in competing uses. In terms of total area in the United States, agriculture is the most significant use of land which competes with timber production. Consequently, models of timber supply require due recognition of agricultural prices. This step is yet to be taken.

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THE TIMBER RESOURCE INVENTORY MODEL'S (TRIM) INTEGRATION WITH THE TIMBER ASSESSMENT MARKET MODEL

Philip L. Tedder[1/]

Abstract.--This paper describes the general format of the timber resource inventory model (TRIM) and the preliminary approach to integrating the model with the timber assessment market model. Start-up procedures for determining the annualized harvest volumes and the management shifting mechanism is presented.

Additional keywords: Simulation, timber supply and demand, Resources Planning Act.

INTRODUCTION

The Timber Assessment Market Model (TAMM, Adams and Haynes, 1980) was developed as an analytical tool to be used by the U.S. Forest Service in projecting future levels of demand and supply of stumpage, lumber, and plywood from our Nation's forests. These projections were an integral part in fulfilling the requirements of the Resources Planning Act (RPA) for 1980. Long-range projections of price, consumption, and production trends were made with the model and used to evaluate the effect of alternative governmental policies on key variables.

Because TAMM was applied in such broad scope it was inevitable that portions of the model would come under careful review from a wide range of concerned individuals, firms, and agencies. One of the most critically analyzed portions of the model was the inventory projection system utilized--the Timber Resource Analysis System (TRAS, Larson and Goforth, 1974). Many shortcomings were found to exist in TRAS for use in national timber inventory projections.[2/] One of the most critical areas of concern was the inability to simulate management intensification on a national scale. It is the purpose, then, of this paper to outline the management intensification approach utilized in the 1980 RPA timber analysis, emphasize two key critical shortcomings of the approach, and suggest an approach that will reflect management intensification efforts in a more realistic fashion in future national timber analyses.

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2/ This author conducted a study to determine the suitability of existing inventory models in national inventory projections. Each model was evaluated against seven criteria that had been identified as lacking in the 1980 timber assessment.

TRAS in the TAMM Model

The TRAS model utilized in the TAMM model is basically the same general model as presented by Larson and Goforth (1974); however, certain changes allowed the model to include price projections generated from TAMM (Alig et al, 1981) and a reflection of management intensification detailed by Barber (1981).

In the current TRAS version, radial growth rates as well as mortality rates and ingrowth (in some regions) are adjusted based on the initial basal area of the stand and current basal area. There are eleven options in the model to ensure that the proper mortality and growth constraints are applied to the specific geographical area. These options allow for the stand to be grown at different rates depending on the intensity of growth. The flexibility in simulating the growth of stands was designed to reflect a concerted effort to accurately reflect the growth of the stand and maintain the biological integrity of the inventory unit.

In the TAMM model, harvest volumes for each ownership are calculated by equilibrating stumpage supply and demand by region/owner group. These harvest levels are then input to the TRAS program which computes a new inventory based on the volumes removed and stand growth. The TRAS program returns the updated inventory to the TAMM program which then uses the inventory information in the private stumpage supply equations. These stumpage supply equations are an integral part of the econometric portion of the TAMM model and are estimated by using the price of stumpage in a particular time period and the level of inventory (obtained from TRAS) at the start of a period. That is, the level of inventory before harvest. That inventory is determined by simply multiplying the trees in each diameter class times the volume per tree for that diameter class. Once the volume per acre for each diameter class is determined, the volumes are summed, then multiplied by the total acres in the ownership.

Management Intensification

It was determined early in the model building process for the TAMM model there would be a need to simulate the effects on volume and growth over time due to intensifying management on the nation's private forest lands. The public forestland's timber harvest was assumed to be the same as calculated in each individual's unit plan. As the TRAS model was the inventory projection process of TAMM, it was necessary to adjust the TRAS program in a fashion that would allow the interpretation of the effects of increased management intensity.

The major reason why this process is needed stems basically from the supply/demand side of the TAMM model and the investment in management intensification.

In the current system, investment opportunities and their financial and physical yield characteristics used were developed by Dutrow et al (1980). These data were intended for use in Chapter 9 of the 1980 RPA analysis and were subsequently utilized in the projection of timber supply. For each supply region and owner group identified in the timber supply analysis, investment opportunities were identified and ranked according to present net worth calculated at different levels of real price growth. The process further assumed that all treatments were to be immediately initiated but at a prescribed rate (Adams et al, 1981). The model employs a decision rule that states that acres will be enrolled in the intensification program at a rate A_i/d_i where A_i is the total number of acres available for treatment for a particular investment (i), and d_i is the duration of the treatment. The duration of the investment was considered to be the time period left between the time the management intensification occurred and the time the acres were harvested. For that duration, the increase in MAI was recorded for each treatment. For a given period of simulation, the change in total volume attributable to the management intensification effort can be calculated.

In some cases, the enrollment time period and the duration of the investment precluded enrollment of all the acres because the total time of the simulation was not long enough. When that happened, only a portion of the acres was enrolled.

The simulation process begins by running the TAMM model to generate a base run using the initial inventories with no adjustment in growth rates. The resulting average stumpage prices obtained are then used to determine for each year which treatment should be implemented. The total increase in increment over the entire simulation is then computed. That is, the increase in increment relative to the base run. For example, assume that the base run started with an increment of 100 and ended with an increment of 105 given the harvests each period and constant diameter growth rates. Utilizing Dutrow's data and the enrollment decision rule, total increment increase over the time period can be obtained. For this example, assume the increment, which is a weighted average for treated and untreated acres, was 10 units. The problem that exists is to adjust the radial growth rates of each diameter class in TRAS to gradually change (simulating the way the growth would actually occur) the ending increment to 115.

TAMM was rerun with the altered TRAS decks (radial growth rates reflecting the management intensification) generating a new price series. A new level of management intensity implied by the new price series was developed and a new TRAS deck (radial growth rates) was calculated.

This process continues until price level changes from one run to the next were not significantly different, implying that any further management intensification effort would yield unacceptable rates of return.

This process generates two problems. The first is that all of the treatments are collapsed into one weighted average (based on treated and untreated acres) response in radial growth rate, thus eliminating the ability to determine actual treated acres and response. The process fairly well approximates the overall response because the process ends up at the precalculated increment level, but arriving at that point is based on variable growth rate manipulation designed to achieve that point. That is, total volume response to commercial thinning in year X cannot be determined, nor can any other response to any type of management intensification effort. In short, the approach assumed that if there are 1000 acres available for precommercial thinning (PCT) and the investment duration is

50 years, then all of the 1000 acres will be precomercially thinned (assuming favorable prices) over a 50-year period. The trouble is that the acres that initially fall into the PCT category will not stay in that category for 50 years. Acres that are originally in one management category will, over time, grow out of that category and be eligible for different treatments.

In discussing the first problem it is evident that only one package of management intensities can be modeled. That package is reflected in the increase in radial growth rates for each diameter class over the entire simulation. These increased rates are phased in over time in a preselected form in an attempt to reflect the increase in growth at the time it is actually observed. The method chosen to phase in the growth rates would almost assuredly have a variable impact on prices calculated in any given time period as well thus affecting the present net worth of the possible management intensities at any given time during the run.

The second problem is that the given management intensity package (again that collection of variable growth rates that, when phase-in is complete, reflects the total increment of all the eligible management intensities) is applied to all acres in the management unit over the simulation. With this approach, alternate management intensity levels cannot be examined and acres treated with one specific treatment cannot be obtained nulifying any solid policy analysis of a specific program. For example, it would be impossible to ascertain the impact of a national policy designed to achieve an 85 percent stocking level on all softwood acres regenerated in the south during the next 50 years. The analysis would require a report specifically indicating acres treated, increase in volume over time and the resulting price impact of such a program. In reality, some acres during the time period would not be regenerated and other levels of management intensification would be occurring as well. In the current approach, all acres would be treated and no additional levels of intensification could be implemented, and the only time periods where one is certain the volume of inventory is correct would be the first and last period.

AN ALTERNATE APPROACH

The two problems outlined with the way management intensification was modeled in the 1980 RPA timber supply analysis can be overcome. However, they can not be overcome within the TRAS system. The TRAS system has been a tried and tested model for many years with good results, but only for inventory updates. Application of the model in a management intensification context for national policy analysis will still have many questions unanswered.

An approach more suitable for making long-range national timber supply projections where specific management intensification information is needed can be found in an acre by age class or yield table projection method.

With the yield table approach, several different levels of management intensification can be modeled for the same initial inventory or portions of it. As the simulation proceeds, present net worth analysis can be performed for different levels of management intensity and an appropriate number of acres can be shifted into the appropriate management classification. For example, say there are two levels of management, 1) plant, commercial thin, harvest, and 2) plant, PCT, commercial thin, and harvest. In a given period, the initial calculations show that all acres that are eligible should be shifted to the highest level. Subsequently, the price impact (negative) generated X years hence because of the increased volume available causes a recalculation of the present net worth. That new value shows that not all of the acres (or none) should have been shifted, rather one-half to the highest and one-half should have remained in the lowest. This type of analysis would be possible under this new procedure and would produce specific information on acres treated. In addition, when those original acres grow out of the range for application of the original management levels, other management levels could be specified that would be more suitable. With any new approach certain problems originate or are imbedded with the process itself. A difficult problem with this approach would be accomplishing an annualized update of inventory levels needed by the stumpage supply equations. A yield table projection can feasibly be operated, assuming the availability of base yield tables, in a periodic fashion rather than annually; conversely, the stumpage supply equations in TAMM utilize annual inventory estimates. This particular problem may be solved by one of several methods; however, the following approach seems to offer the best alternative.

1. The yield table projection method could be run initially five periods (50 years) for each region/owner group with a reasonable set of harvest levels determined exogenously.

2. An estimate of the periodic annual increment (PAI) for each decade will be determined. For the first decade, the PAI will be determined by:

$$PAI_{\text{first decade}} \; [I_1-H_1+I_{10}]/10$$

where I_1 and I_{10} are inventory levels before harvest in the first and tenth periods. H_1 is the 10-year exogenously supplied harvest level.

3. Passing the necessary before harvest inventory levels and the decadal PAI to TAMM, annual harvest volumes (h) can be determined. I_1 is used to calculate h_1 and a simple growth/drain model can be used to calculate the remaining harvests. The second year harvest, h_2 , requires I_2. I_2 can be found by:

$$I_2 = I_1-h_1 + PAI$$

Annual harvest volumes can then be found in a similar manner.

4. After the tenth calculation of the annual harvest, h is summed, $\sum_{t=1}^{10} h_t$, and checked to see if it is within some prespecified tolerance level with H_1 as follows:

$$\frac{\left|\sum_{t=1}^{10} h_t - H_1\right|}{\sum_{t=1}^{10} ht} \leq \text{tolerance}$$

If it is, then the second decade's harvests can be calculated with TAMM. If it is not, the H_1 is replaced with $\sum_{t=1}^{10} h_t$ and TRIM is run again. This sequence continues until the tolerance check is met for all periods.

A second problem with the yield table/age class approach is how to phase in the management intensification. The previous approach, as indicated earlier, assumed that all acres received a basic package of intensification. With the age class approach, the inventory can be distinguished between sites, species, stocking levels, and ages of which any combination may warrant entirely different treatments. With this being the case, for each combination a set of treatments can be specified for each age and site class. When the acres grow out of one age class to another, they could be eligible for another set of treatments.

The process for determination of shifting from one level to another must have dual purpose. The first must be a process that will allow total prespecification of acres treated in any category. This approach allows determination of "what if" policies. The second must be a process that reflects investment behavior under rational expectations. Rational expectations would assume investment in a management intensification effort if the estimated rate of return on the investment was at least equal to or greater than the alternate rate of return.

An example of the economic process will clarify the details of its operation. Costs and yields used in this example were drawn from the recent work of the Pacific Northwest Regional Commission, Forest Policy Project, Timber Supply Module (Rahm, 1981). For the Pacific Northwest Westside region, low site, Douglas-fir type, assume that five MI levels are available as follows:

MI1--clearcut and regenerate only (custodial management),
MI2--MI1 + 1 thinning at age class 6,
MI3-MI2 + 1 additional thinning at age class 7,
MI4--clearcut, regenerate with genetically superior stock, 1 thinning at age class 4,
MI5--MI4 + 1 additional thinning at age class 5.

Assume also the following economic parameters:

discount rate 5 percent real,
regeneration cost \$100.00/acres,
thinning cost \$600.00/acre,
rotation length 80 years (age class 9).
delivered wood price \$3/cubic foot

These costs and rotation could also vary by MI class, but are assumed to be uniform here for simplicity. Also, the interest rate could vary by owner class. A yield table describing the residual (or clearcut) and thinning volumes of stands under each MI class is developed (for the conditions of the example) as follows:

Age Class	MI1		MI2		MI3		MI4		MI5	
		Thin	CC	Thin	CC	Thin	CC	Thin	CC	Thin
1	0		0		0		0		0	
2	0		0		0		1500		1500	
3	1500		1500		1500		3000		3000	
4	3003		3003		3003		4100	400	4100	400
5	4180		4180		4180		5000		4640	360
6	4590		4230	360	4230	360	5464		5400	
7	5030		5330		4960	370	5961		5900	
8	5480		5825		5900		6469		6500	
9	5980		6375		6460		6800		6800	
10	6530		6980		7060		7200		7200	
11	7030		7530		7620		7700		7700	
12	7480		8025		8124		8200		8200	
.	.		.		.		.		.	
.	.		.		.		.		.	
.	.		.		.		.		.	
20	8230		8850		8964		9000		8900	

Certain rules to insure logical consistency and biological feasibility are also required.
(1) Acres can be shifted from MI1 to MI2 or MI3 at any age up to and including age class 6 but not later.
(2) Acres can be shifted from MI2 to MI3 at any time up to and including age class 7 but not later.
(3) Only nonstocked or bare land can be shifted into MI4 and MI5.
(4) Acres in MI4 can be shifted into MI5 up to and including age class 5.
(5) Once an acre is shifted to an MI class it cannot be shifted back to a lower MI class if an activity has occurred in the higher MI level. Given the conditions above, a table of discounted costs is then computed for each age and MI class (an infinite series of rotations is used).

Present Net Worth of Costs Per Acre by MI Class

Age Class	MI1	MI2	MI3	MI4	MI5
1	102.06	155.46	188.24	243.75	330.73
2	3.35	90.33	143.73	234.14	375.83
3	5.46	147.15	234.13	381.39	612.18
4	8.90	239.69	381.38	621.26	997.19
5	14.50	390.43	621.22	34.62	646.98
6	23.62	635.97	1011.90		
7		58.59	670.95		

Each entry represents the present value of future costs for stands of a particular age. For example, a stand in MI3 at age 40 (age class 5) will incur an immediate cost of $621.22.

Prices for each ten-year interval into the future may be obtained from a previous run of TAMM (they are assumed to be constant at $3/cubic foot in this example) and combined with the above yields. The present value schedule on a perpetual basis follows.

Present Value of Returns

Age Class	MI1	MI2	MI3	MI4	MI5
1	369.43	489.95	555.85	703.46	860.03
2	601.76	798.08	905.42	1145.86	1400.89
3	980.20	1299.98	1474.83	1866.89	2281.90
4	1596.65	2117.54	2402.35	3040.30	3716.98
5	2600.78	3449.25	3913.17	2997.65	4099.89
6	4236.39	5618.46	6374.15		
7	6900.63	7392.67	8623.62		
8	11240.40				
9	18309.43				

Combining the present values with the costs yields the net present value for each MI and appropriate age class for a perpetual series.

Net Present Value of Returns

Age Class	MI1	MI2	MI3	MI4	MI5
1	291.37	334.49	367.61	459.71	529.30
2	598.41	707.75	761.69	911.72	1025.06
3	974.74	1152.83	1240.70	1485.09	1669.72
4	1587.75	1877.85	2020.97	2419.04	2719.79
5	2586.27	3058.82	5362.25	2963.03	4746.87
6		4982.49	7952.67		

In this case bare land (age class 1) would find its highest return by shifting to MI5. Stands currently 40 years old in MI1 cannot be shifted to MI4 or MI5, but could increase their present value by shifting to MI3. STands in MI2 would shift to MI3.

Given externally specified limits on acreage shifts, acres would then be transferred (as indicated above) among the various MI classes within each age class. A similar process would be repeated for all owners, species, and site classes.

In this example, expected future prices are derived from a previous TAMM run and do not change during the projection period. The approach, however, will allow virtually any specification of the price expectations mechanisms, including fixed expectations (of the sort used in the example) expectations based on recent historical experience with price growth or levels (expectations a distributed lag of past levels or rates), or rational expectations are actually realized. In the latter case, the same mechanism indicated earlier would be utilized with one exception. Harvest levels would be equilibrated over the five operiods without altering the initial investment scheme. Once the TAMM model was equilibrated with TRIM, the new TAMM price series will be entered in TRIM and the process will begin again. The inventory level before harvest, I, is the key variable and will guide the iteration process.

CONCLUSION

The 1980 RPA timber supply projection process made great strides in the ability to make long-range forecasts of timber supply. The inventory projection process, because of the very nature of its design, was unable to answer important questions concerning theimpact of various investments in management intensification on the nation's forest. This problem stems from the fact that the TRAS system treats every acre identical, both biologically and economically whereas each acre is different in each category.

Work is underway to replace the stand table projection method with a yield table projection method. The process for solving the problems indicated in this paper have been developed but there are other problems that a yield table approach could have. The first, and most immediate, is the availability of yield tables for the major species in the different geographical areas to be modeled. Another problem area is the determination of yield generated when a treatment like commercial thinning is applied. These problems can be solved, however, by using some of the excellent growth yield models that have been developed in the past few years.

When the system is complete, and the data has been assembled, a new and vastly improved policy analysis tool will be available that will assist our nation's forest policymakers in their efforts to increase the productivity of our nation's forest.

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ESTIMATING THE RESPONSE OF NONINDUSTRIAL PRIVATE FOREST LANDOWNERS TO INVESTMENT OPPORTUNITIES AND PUBLIC PROGRAMS

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Abstract.—Improving economic opportunities to increase timber supplies from nonindustrial private landholdings calls for new models of landowner investment responses. Past studies of landowner response are of limited usefulness for the development of a composite model of forestry investments and subsequent supply contributions of private forest owners. A survey of landowner decisions following harvesting in the southern United States is underway to examine market influences on pine management decisions and needs, if any, for remedial public programs. Estimates of investment opportunities are also being updated. Methods are being developed to merge assessment of economic opportunity and landowner response with national timber supply models.

INTRODUCTION

Forest policy and planning decisions require reliable information on investment opportunities, responses of landowners to opportunities, and on public programs that may elicit landowner response when markets fail to do so. Recent national and regional data on timber price trends, stand conditions, and treatment options show a favorable investment climate emerging for intensified forest management in the United States. In 1980, the Forest Service of the U.S. Department of Agriculture (USDA) assessed the nation's forests and rangeland situation. They estimated that about 160 million acres of private commercial forestland, some 30 percent of the nation's total, could yield returns (measured in real dollars) of 4 percent or more on investments in reforestation, stand conversion, and stocking control.

If all these opportunities were realized, net annual timber growth in the United States could increase by almost 13 billion cubic feet, a volume roughly equivalent to the total net annual growth nationwide in 1976. But this level of production would require an investment of some $13 billion—a sizable sum of capital considering the vast number of landowners that must amass or direct such capital.

Though nonindustrial owners hold only 58 percent of U.S. commercial timberland, they have 75 percent of the forest acres promising a 4 percent or greater return. About three quarters of these promising nonindustrial areas are in the U.S. South. The skewness toward nonindustrial private holdings suggests a need to consider carefully the myriad of independent decisions they will make on their woodland operations.

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At present, researchers at the Southeastern Forest Experiment Station have found that about 60 percent of the pine stands harvested on nonindustrial ownerships are not regenerating to pine. Cutover lands in the South typically regenerate to mixed stands of pine and hardwoods with less commercial value. With each successive state forest inventory in the South (excluding Oklahoma), a decline in the ingrowth of 2- to 4-inch pines to the 6-inch diameter class has been observed. This translates into reduced volume estimates for the period 30 to 50 years from now, a situation that promises to exacerbate either the historical rise in softwood stumpage prices or the undesirable import situation.

THE NEED FOR INVESTMENT MODELS

The difference between investment potential and investment behavior raises questions: To what extent will landowners sieze economic opportunities to invest in forest management? And if investment incentives fail, what cost effective public programs will prompt landowner actions? But if owners are able to take advantage of some of the seemingly favorable investment opportunities, or if public programs have effects what will be the impacts on prices and import levels?

Investment levels will probably never be sufficient to capture all opportunities defined by the Forest Service in the 1980 Resources Planning Act assessment. The 124 million acres, nationwide, and the 89 million acres, southwide, with 4 percent or greater investment opportunities represent only theoretical maxima.

Before an accurate timber supply model can be developed, estimates must be made of probable landowner response under differing market conditions, social settings, and policy alternatives. An accurate and current model of forestry investment behavior must be developed to allow (1) the translation of acres needing silvicultural treatment into acres likely to receive that treatment, and (2) the appraisal of market performance and the effectiveness of public programs in allocating timber resources. Such a model would allow more realistic future projections of timber supplies and formualtion of public programs.

PAST LANDOWNER RESEARCH

A vast literature on landowners and landownership has accumulated in the past several decades. Some 100 to 150 empirical surveys of landowners have been conducted since the 1940's. These, together with numerous related studies, offer us a legacy of inference, speculation, debate, and innuendo on the forestry-related behavior of landowners. Without new modeling efforts, we must depend on these past studies to piece together a composite view of landowner performance and begin building theories of behavior. But past data are piecemeal, fragmented, and often narrowly focused, making the exercise of model building analogous to predicting human behavior from a series of old and faded snapshots. Because of methodological deficiencies and lack of continuity of data over time and across geographical regions, past studies afford us only limited opportunities to draw definitive conclusions about the market as an allocator of timber resources and the potential success of remedial public programs.

Based on their primary objectives, landowner studies may be classed in one of two general categories--descriptive or analytical. Descriptive surveys generate a statistical profile of the landowners in a specific geographic area such as a state or a physiographic region; analytical surveys relate sets of independent variables such as age, income, and occupation to one or more dependent variables, usually some measure of a forestry-related activity such as harvesting, investment, or participation in public programs. These categories are not mutually exclusive; some surveys exhibit both descriptive and analytical features. The categories do, however, offer a means to look at past studies and judge their merit.

Some Results from Descriptive Studies

Descriptive surveys profiling forest landowners and characteristics of their landholdings in all or parts of 22 states are summarized in Table I. These studies represent a majority of past efforts to profile the owners of private forest lands in the major political and physiographic regions of the United States. The items profiled are a selection of variables commonly found in landowner studies. Note that surveys that sample one acre minimum parcels characterize much different populations from those studies sampling 3, 5, 10, or 20 acre minimum parcels. With these limitations, Table I suggests several conclusions.

Problem Heterogeneity. Descriptive surveys have always found landowners a diverse group. Except for McClay (1961), who compared landowners from nine county and multi-county regions in eight eastern states, past surveys have not addressed spatial variation. Without measures of regional differences in nonindustrial forest owners, it is difficult to infer the extent of problems.

The great variation among attributes profiled in Table I suggests that the nonindustrial landowners are indeed heteorgeneous, despite biases created by study design. For example, in each survey in New England, the proportion of farmers owning forest acreages is less than 5 percent. In other regions this proportion frequently reaches 20 to 30 percent. Conversely, the proportion of business and professional people holding forest land in New England is high. These and other differences suggest that only programs tailored for regional situations will improve outputs of nonindustrial forest lands.

Landholdings. Landholdings in some states and regions are more fragmented than in others. Populations of landowners holding those lands also change markedly during a 20-25 year period. In many states, parcels of less than 100 acres comprise well over 90 percent of the landholdings, but in other states this proportion is much less. Turnover rates also vary, but are sufficiently high throughout the states to conclude that 50 to 75 percent of ownerships will change hands every 20-25 years. These dynamics of landownership have not been well documented in past research.

TABLE 1. Selected Characteristics of Nonindustrial Private Forest Ownerships and Owners From 21 Major Descriptive Surveys Covering All or Parts of 22 States, 1959-1978

			LANDHOLDINGS					CHARACTERISTICS				
			Minimum Size Sampled	Estimated	Under 100 Acres		Tenure	Bus. & Prof.		Farmers		Resident Owners
STATE	STUDY	YEAR	(acres)	Number	(pct. bldg.)	(pct. land)	(pct.> years)	(pct. owners)	(pct. land)	(pct. owners)	(pct. land)	(pct. owners)
ALABAMA	Somberg	1971	20	-	50	(-)	58 > 20	16	(-)	30	(-)	78
ARKANSAS (Southwest)	Perry & Guttenberg	1959	3	55,000	87	(40)	19 > 25	12	(27)	35	(26)	44
DELAWARE	Kingsley & Finley	1975	1	11,400	94	(48)	22 > 25	0	0	43	(57)	78
GEORGIA (Piedmont)	Holemo & Dyson	1971	5	-	68	(-)	-	19	(22)	29	(61)	-
GEORGIA (Coastal Plain)	Holemo & Dyson	1975	5	-	53	(8)	-	19	(29)	40	(44)	-
KENTUCKY	Birch & Powell	1978	1	427,200	97	(55)	21 > 25	15	(16)	25	(35)	65
LOUISIANA	Marlin	1978	20	112,260	71	(-)	50 > 25	18	(-)	13	(-)	48
MISSOURI (Wayne County)	Farrell	1964	3	-	37	(3)	23 > 25	26	(39)	28	(20)	47
MICHIGAN (Upper Peninsula)	Stone	1969	5	-	77	(-)	-	17	(36)	7	(8)	76
MICHIGAN (Upper Peninsula)	Quinney	1962	5	30,000	81	(-)	-	14	(-)	9	(-)	81
MICHIGAN	Schallau	1964	3	182,000	-	(-)	34 > 20	12	(18)	22	(19)	38
NEW HAMPSHIRE	Kingsley & Birch	1977	1	85,600	92	(24)	16 > 25	50	(52)	1	(7)	83
NEW JERSEY	Kingsley	1975	1	63,600	98	(84)	21 > 25	42	(50)	3	(6)	73
NORTH CAROLINA	Pomeroy & Yoho	1964	1	225,600	82	(31)	-	11	(18)	36	(38)	67
PENNSYLVANIA (S.E., S.W. Poconos)	Larsen & Gansner	1972	-	300,000	57	(-)	50 > 20	36	(-)	20	(-)	72
VERMONT	Kingsley & Birch	1977	1	73,900	85	(25)	16 > 25	41	(47)	10	(20)	83
WASHINGTON (Western)	Koss & Scott	1978	20	36,000	-	(-)	39 > 25	-	(-)	-	(-)	-
WEST VIRGINIA	Birch & Kingsley	1978	1	207,500	91	(35)	41 > 25	7	(21)	16	(22)	44
WISCONSIN (Central)	Sutherland & Tubbs	1959	3	-	87	(-)	-	9	(-)	52	(-)	64
S. NEW ENGLAND (Conn., R.I., Mass.)	Kingsley	1976	1	184,000	95	(57)	25 > 25	46	(45)	4	(10)	87
NEW ENGLAND	Barraclough & Rettie	1950	10	-	71	(45)	33 > 20	18	(-)	19	(-)	65

TABLE 1 - (Continued)

STATE	STUDY	YEAR	ACTIVITIES: Harvested Timber (pct. owners)	(pct. land)	Improved Woodlots (pct. owners)	(pct. land)	OBJECTIVES: Timber (pct. owners)	(pct. land)	Speculation (pct. owners)	(pct. land)	Recreation (pct. owners)	(pct. land)	Residence (pct. owners)	(pct. land)
ALABAMA	Somberg	1971	-	(-)	-	(-)	-		-		-		-	
ARKANSAS (Southwest)	Perry & Guttenberg	1959	55	(-)	-	(-)	65	(-)	5	(-)	-	(-)	5	(-)
DELAWARE	Kingsley & Finley	1975	46	(75)	-	(-)	3	(17)	17	(11)	3	(7)	64	(49)
GEORGIA (Piedmont)	Bolemo & Dyson	1971	44	(91)	20	(84)	-	(-)	-	(-)	-	(-)	-	(-)
GEORGIA (Coastal Plain)	Holemo & Dyson	1975	49	(58)	25	(88)	29	(30)	18	(11)	2	(11)	6	(2)
KENTUCKY	Birch & Powell	1978	38	(54)	-	(-)	3	(9)	5	(13)	1	(2)	19	(10)
LOUISIANA	Marlin	1978	53	(-)	9	(-)	56	(-)	-	(-)	4	(-)	-	(-)
MISSOURI (Wayne County)	Farrell	1964	-	(-)	10	(40)	15	(-)	11	(-)	4	(-)	11	(-)
MICHIGAN (Upper Peninsula)	Stone	1969	-	(-)	-	(-)	11	(22)	7	(18)	33	(21)	21	(9)
MICHIGAN (Upper Peninsula)	Quinney	1962	24	(-)	6-13		5	(7)	6	(26)	28	(13)	19	(12)
MICHIGAN	Schallau	1964	50	(-)	5-6		19	(-)	4	(-)	18	(-)	18	(-)
NEW HAMPSHIRE	Kingsley & Birch	1977	24	(66)	18	(58)	4	(23)	7	(19)	20	(22)	55	(17)
NEW JERSEY	Kingsley	1975	11	(26)	13	(25)	1	(2)	28	(38)	12	(12)	47	(28)
NORTH CAROLINA	Pomeroy & Yoho	1964	59		24		35	(46)	5	(8)	-	(-)	3	(1)
PENNSYLVANIA (S.E., S.W.	Larsen & Gansner	1972	21		5-38		22	(-)	19	(-)	20	(-)	24	(-)
VERMONT	Kingsley & Birch	1977	24	(66)	18	(53)	7	(19)	18	(14)	23	(22)	33	(21)
WASHINGTON (Western)	Koss & Scott	1978	53		-		26	(-)	8	(-)	19	(-)	16	(-)
WEST VIRGINIA	Birch & Kingsley	1978	41	(61)	-		3	(19)	10	(10)	10	(9)	23	(10)
WISCONSIN (Central)	Sutherland & Tubbs	1959	24	(-)	2-3		49	(-)	-	(-)	-	(-)	-	(-)
S. NEW ENGLAND (Conn., R.I., Mass.)	Kingsley	1976	13	(31)	12	(30)	4	(8)	17	(19)	17	(21)	39	(27)
NEW ENGLAND	Barraclough & Rettie	1950	53	(-)	-	(-)	43	(62)	15	(10)	20	(23)	16	(9)

Landowner Characteristics. Only three of many landowner characteristics--proportions are presented in Table I: (1) business and professional people, (2) farmers, and (3) residents of their properties. Though the large majority of studies found the greatest proportions of forest landowners to be farmers and business/professional people, the proportions of landowners in these categories vary among regions. This suggests that many forest landowners, particularly the owners of large acreages, must keep their land in a productive state through agriculture or have sufficient wealth to hold the land without keeping it in production.

Other characteristics were not measured in comparable units or they did not vary significantly from study to study. With income and education measures, time dependent effects had an overriding influence, rendering comparisons virtually impossible. In the case of age, the model category was almost always 50 to 60 years. Absentee ownership of forest property varies somewhat among states and regions, ranging on the average from 10 to 20 percent of the owners.

Landowner objectives. Landowner intentions vary widely within and among states and regions. Timber management objectives are shown to be lower in the North than in other areas, whereas recreation tends to be greater in that region, particularly in New England and upper Michigan. Moreover, the proportion of land held by owners with timber objectives tends to be high relative to their numbers, whereas the proportion of land held by owners with recreation objectives tends to be low relative to their numbers.

Landowner Activities. The statistics on harvesting and investment activities in Table I represents a variety of measurement techniques over varying time periods. For example, investment in forestry in some studies was measured as participation in a public assistance program; in other studies it was any of a series of land treatments. Harvesting, likewise, has veen variously measured, particularly with respect to time. Some studies asked only about harvesting activities that occurred while the land was owned; others have asked about harvesting activities over a 5-year, 10-year, or longer time interval. Interpretations of harvesting and investment data are difficult and there is no clear basis in past landowner studies for concluding that the harvesting or investment levels are too low or too high.

Some Results from Analytical Studies

Attempts to associate landowner and landholding characteristics to forestry-related behavior have revealed numerous relationships. Many of these are evident in the results of the 18 major analytical surveys summarized in Table II. But only general observations and conclusions are reported in Table II; no attempt is made to screen surveys on the basis of quality or statistical rigor.

Size of Ownership. The most common finding is a relationship between the size of landholdings and landowner performance. With one exception, forestry-related behavior was found to be "better" on large tracts than on small tracts. This relationship has both economic and social/psychological interpretations. Economies of scale affects the profitability of forestry because rates-of-return are generally greater on large tracts of land. Another reason size is

TABLE II. A Summary of Relationships Between the Independent and Dependent Variables of Past Analytical Studies of Nonindustrial Private Forest Owners, 1944-1972

STUDY/YEAR	DEPENDENT VARIABLES	Positive Interest and Attitude	Businessmen and Professionals	Received Public Assistance	Amount of Forestland	Length of Tenure	Size of Holdings	Asset Position	Farm Operations	Type of Farms	Occupation	Residence	Education	Age
Folweiler and Vaux (1944)	Pine Stocking Index						+	–			–	–		
Chamberlain et al. (1945)	Pine Stocking Index		+				–							
Barraclough and Rettie (1950)	Objectives						+				+			
James et al. (1951)	Cutting Practices	+										+		
Mignery (1956)	Management		+	+										+
Pleasonton (1957)	Management													+
Yoho et al. (1957)	Cutting Practices	+				+						+		+
Yoho and James (1958)	ACP Participation											+		
McDermid et al. (1959)	Management						+	+				–	+	–
Perry and Guttenberg (1959)	Management		+				+	+			+			+
Sutherland and Tubbs (1959)	Interest in Forestry													+
Webster and Stoltenberg (1959)	ACP Participation						+	+			–			
Muench (1964)	Programs Participation	--	+				+			–	+	–	+	–
Fruthchey and Williams (1965)	Practice/Adoption Index	+	+				+				+	–	+	+
South et al. (1965)	Adopters	+		+	+		+	+	+	+	+			+
Anderson (1968)	Attitude Toward Forestry		+								+			+
Stone (1969)	Harvesting/Intentions						+							
Larsen and Gansner (1972)	Harvesting/Intentions			+		+/–	+	+			+	–	–	–

A "+" indicates relationship was explored and observed
A "-" indicates relatiohship was explored but not observed

important is that large landowners may be forced to consider forestry to offset the costs of holding large land acreages for non-pecuniary purposes. Past surveys have left open the questions of means and ends.

Economic versus Social/Psychological Determinants. Two fundamental perspectives have either implicitly or explicitly shaped much past research on landowner behavior. The economic perspective has prompted the examination of profit as a motive for practicing (or not practicing) forestry; a social/psychological perspective has prompted the examination of non-forestry motives.

In economically oriented surveys, landowners have been viewed as profit maximizers. It is assumed landowners are willing to capitalize on opportunities to gain from forestry when those opportunities are available. Explanations of landowner behavior in these studies have centered almost exclusively on production economics and pecuniary incentives.

The social/psychological impetus for landowner studies considers the utility of landowners from both pecuniary and non-pecuniary gains. Landowners in these studies have been viewed as maximizers of personal utility which, may or may not involve profit from timber management or harvesting.

In combination, economic and social/psychological perspectives have fostered two basic conceptions of landowner behavior--one oriented toward production, the other oriented toward consumption. But beyond sketching these general frameworks, past surveys have not exhaustively explored their fine points or their relative importance. Both economic and social/psychological determinants are likely to influence landowner behavior, but for whom, when, where and exactly how has not been adequately researched.

Publicly Desirable versus Individually Rational Behavior. A basic shortcoming of many past analytical surveys has been use of dependent variables derived from publicly desirable rather than individually rational levels of performance. It appears much easier to determine what is publicly desirable than what is individually rational. Analytical studies such as those in Table II have often revealed factors associated with deviations from some publicly desirable level of performance, but have not revealed factors associated with deviations from behavior considered rational from an individual's point-of-view. As a result, little information exists on the extent of profitable opportunities being forgone, or the extent of non-economic forestry practices. Without such data, judgements about the rationality of individual landowner performance are highly subjective.

Ability and Inclination. The ability and inclination of landowners to practice forestry have been natural derivations of economic and social/psychological theories. As such, they have been explored extensively in past research and found to be positively associated with forestry-related behavior. Ability to invest in forestry has been measured variously as income, occupation, education, and size of holding. The higher the measures of these variables, either separately or combined in indices, the more likely the landowner has engaged in forestry, participated in public assistance programs, or improved productivity.

The inclination to practice forestry has been measured variously as education levels, objectives, length of tenure, residency, size of holding, and attitudes. Landowners with greater knowledge and propensity to practice forestry tend to be more inclined to invest and harvest.

Relationships between forestry-related activities and variables measuring ability and inclination are evident in numerous studies summarized in Table II. Unfortunately, however, no past survey has explored the relative importance of ability and inclination for a population of landowners. We thus, do not know the degrees to which we have financially able owners without an inclination toward forestry versus inclined owners without the financial ability.

Conclusions on the usefulness of past surveys

Several design drawbacks are evident in both descriptive and analytical surveys. Most descriptive studies have been piecemeal and fragmented, with narrow geographic focus, small sample sizes, and varying sample units. Only rarely have they attempted to maintain continuity over time and across regions. As a group, descriptive studies have lacked a systematic means of compiling landowner information.

These shortcomings severely limit the usefulness of the studies' ability to aggregate data for decision-making purposes. Past descriptive surveys have varied too widely in their questioning and design to permit regional and other views of landowners which are critical to the analysis of behavior. Comparable landowner data, coincident with political boundaries that can be aggregated or disaggregate as needed, is needed to compare and contrast landowners and identify ramifications of proposed actions.

The primary shortcoming of analytical surveys are their inordinate preoccupation with (1) deriving dependent variables from publocly desirable, rather than individually rational, levels of landowner performance and (2) identifying short-term psychogenic rather than long-term sociogenic determinants. Assessing landowner performance only from the public's point-of-view limits the understanding of aspects of landowner behavior from what would be considered individually rational, given normal value orientations. Conceivably, landowner behavior may not deviate widely from what most individuals would do, given the social, economic, and cultural climates for forestry and the specific circumstances involved in each case. In particular, it is necessary to link landowner behavior to investment opportunities evaluated from the landowner's point-of-view to assess gaps in landowner performance.

A closely related problem is consistent use of landowner characteristics as independent variables to "explain" landowner performance. Psychogenic factors as measured by various demographic factors may be proximate, short-term "causes" of forestry-related behavior. But they may not be the ultimate determinant of outputs from nonindustrial private forestlands. Broader, sociogenic determinants such as markets, tax policies, assistance programs, and cultural influences may play a more important role. But these broader determinants have not been adequately explored in past landowner research.

New analytical and descriptive surveys must be designed and administered to obtain data to develop models of landowner behavior. New surveys are needed which yield data that: (1) can be aggregated and disaggregated to various regional levels; (2) explore the influences of both sociogenic and psychogenic factors; and (3) link landowner behavior to investment opportunities. Without such information, we cannot understand landowner behavior relationships to markets and public programs and make informed policy decisions.

CURRENT LANDOWNER RESEARCH

A project to develop new insights on landowner behavior is currently underway in the 12 states comprising the southern pine region. Researchers from the USDA Forest Service and Duke University are surveying landowners who own land from which they, or a prior owner, have harvested timber during the past 10 years. The primary purposes are to identify management decisions being made following timber harvest and to link this landowner behavior with measures of economic opportunity. Preliminary results of a pilot survey completed in North Carolina in August 1981, suggest a very small number of owners (less than 10 percent) engage in reforestation after harvest.

A cooperative agreement with the USDA Statistical Reporting Service (SRS) made the survey possible. Each June the SRS surveys agricultural activities of landowners and farm operators within randomly selected geographic areas called segments. Since these segments typically include forested land, the June Enumerative Survey (JES) could be expanded to timber harvesting and other forestry-related activities.

In 1981, JES interviewers in the study area developed a sample of approximately 1000 recent timber harvesters by asking all landowners and operators within each segment the following screening question: Has timber been harvested for commercial wood products from your land within the past 10 years? Each sample landowner is now being visited by an SRS enumerator and asked a series of questions about his recently harvested parcel. The questions cover the characteristics of the landholding, forestry practices, methods of harvest, methods of reforestation (if any), costs, use of public assistance, rationale for decisions, and possible effects of alternative public incentives.

We expect to complete the final tabulation of results in early summer 1982. The study will be the most comprehensive examination yet of reforestation decisions. Upon completion of the full southwide survey, a composite of reforestation activities, a lack thereof, will be developed for the entire southern pine region.

AN UPDATE ON ECONOMIC OPPORTUNITIES AND METHODS FOR LINKING OPPORTUNITIES TO SUPPLY ESTIMATES

Another element of the research necessary to model the private forestry sector is a cooperative study by the USDA Forest Service, the National Forest Products Association, and Duke University to update the 1978 study on economic opportunities to increase timber supplies in the U.S. In that study, regional panels and state committees, involving over 400 forestry experts from government, industry, and universities identified opportunities to increase timber production in specified forest types and conditions, estimated increments in growth, management costs, and projected timber values. Forest Inventory Units in the Forest Service estimated the area for each treatment opportunity by ownership, physiographic region, and site condition.

Updating the data for 1984 will be a much less ambitious effort. Each of the 1978 panel and committee members has been asked to review the cultural treatments, yields, costs, values used, and suggest changes where warranted by newer information and technology. Their recommendations will be combined with the earlier acreage data to project revised estimates of economic opportunities to augment timber supplies.

Linkage to the U.S. softwood timber model will be undertaken when this new data base is available. If investors sieze even a fraction of the opportunities to increase timber growth, more wood will move to future markets affecting supplies, demand, and resultant prices. Dampened price expectations will adversely affect profit expectations for the remaining treatment opportunities. Additional treatment opportunities should be enrolled until the resultant price expectations fall to the point where further treatment of acres promises uncompetitive rates of return on investment. From these iterative calculations, estimates can be made of future timber supplies under intensified management, prevailing stumpage prices, and import-export ratios.

Needless to say, these are important projections for formulating forest policy and programs. But limited by current information, the projections are not linked to behavior of nonindustrial owners in terms of the levels of investments that are likely to occur or the rate at which they will take place. The current pine reforestation research at Duke may provide some insights.

An interesting addendum to the descriptive aspect of the reforestation survey will be an analysis of the economic opportunities associated with each of the recently harvested parcels. Computing an index of economic opportunity for recently harvested sites and comparison to landowners behavior will provide a measure of the economic rationality of landowner performance; that is, the extent to which behavior corresponds to economic opportunities. This will offer a means to appraise the effectiveness of the marketplace and the corresponding need for public programs.

SES's area frame sampling method allows the recently harvested sites to be located on aerial photographs and data compiled on site characteristics from soil surveys and other secondary data sources. Site specific data are currently being developed for each of the approximately 1000 harvest parcels in the southwide study, and various indices of economic opportunity are being com-puted. Factors to be considered are input data from two principal categories: (1) the biological growth potential of the site, and (2) the economic climate expected for the site over the management period.

In the reforestation study, estimates of acreage, stocking, and site index are being developed using aerial photos, landowner interviews, and soil surveys. These data can be used to determine how well the harvested sites will grow another timber crop. The estimates of current prices, price trends, and management costs will be used to simulate the economic climate facing various owners. The analysis will yield indices of economic opportunity such as present net worth or internal rates of return that can be compared with actual landowners behavior.

The final analysis of the investment behavior of landowners will make preliminary determinations of the efficiency of the nonindustrial sector of the softwood timber market in the South. The analysis will represent an important first step towards linking landowner behavior, economic opportunities, and timber supplies in regional and national models.

EVOLVING METHODOLOGY FOR FUTURE RPA ASSESSMENTS

Substantial increases in the quantity and quality of information are planned for the 1990 RPA Assessment and Program. Goals will be set for each of many outputs of our forest and rangelands. Establishment of goals will pave the way for driving specific objectives in terms of timing, and levels of production will be projected for each of the outputs. This undertaking calls for more and better information on cost-effective opportunities for productivity. The State and Private Forestry branch of the Forest Service will then plan programs to achieve specific objectives of timber production. In the short-run, the only options are improving utilization of harvested wood fiber. In the long term, forest management opportunities offer means of increased timber output. To achieve timber objectives, each state must be able to assess its ability to increase net annual timber growth on state-owned and private lands. Productive potential of State and Private Forestry across the nation would be an aggregate of opportunities in the 50 States, with selection criteria based on economic efficieon economic efficiency.

The conceptual framework is sound, but the underlying data base is absent. Increased productivity on private nonindustrial ownerships can be scheduled, but realistic assessments of attainment can not be projected until probable levels of investments by these owners under various public programs can be determined. Our lack of knowledge about forestry investments by private owners is an ever present stumbling block.

SOME CONCLUDING THOUGHTS

New dimensions of forestry must be considered because most U.S. government agencies will be functioning in a new arena in the 1980's. The decade will be one of quantification and accountability, with growth in federal budgets projected to lag behind growth in the 1960's and 1970's. Cost-effectiveness and attainment of social goals will be criteria for the establishment and survival of government programs. Only by analyzing investment responses among the owners of the nation's forestlands and translating that information into information for congressional and administrative budget analysts can we identify the proper share of dollars for public forestry programs.

Just as the 1970's differed from the 1960's, the 1980's will bring changes that will influence resource supply and demand and, consequently, planning. Inflation, energy, transportation systems, international relations, and urbanization will all have impacts on the supply and demands for outputs from non-industrial private forest lands. Shifts in planning will necessitate new approaches based on a revised understanding of the factors that influence supply and demand.

Designing a model system to track all data needed for planning is not feasible because of costs. We must determine which data are important and the various factors that influence landowner behavior. We must then relate resource information to planning processes, design systems to monitor trends, and develop models to evaluate alternative plans in light of social goals.

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ESTIMATING THE EFFECTS OF MULTIRESOURCE AND ENVIRONMENTAL OBJECTIVES IN MODELING TIMBER SUPPLY

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Abstract.--A multilevel operations research modeling approach can be used in analyzing supply-side trade-offs in national assessments of renewable resources. The reasons for undertaking such an analysis are discussed and the need for joint cost analysis is analyzed cursorily. Finally, the advantages and disadvantages of the proposed analysis approach are identified.

INTRODUCTION

Section 2 of the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA) specifies the following tasks (among others) for National Assessments of renewable resources in the United States:

(1) an analysis of present and anticipated uses of, demand for and supply of the renewable resources, with consideration of the pertinent supply and demand and price relationship trends, and
(2) an evaluation of opportunities for improving renewable resource yields of tangible and intangible goods and services, together with estimates of investment costs and direct and indirect returns to the Federal Government.

This is, broadly, the impetus for the topic of this paper. Though the title is oriented toward timber supply analysis, the topic could be generalized as, "estimating supply-side trade-offs between timber and other renewable resources."

A number of analytical approaches could be considered to attack this problem, including:

(1) simulations of ecological systems, including projections of biological growth,
(2) econometric estimation of production functions,
(3) econometric simulation of market or quasi-market equilibria, and
(4) optimization modeling of the production system.

The first two of these approaches focus on strictly biophysical production relationships, while the last two can be used to add cost dimensions to the analysis. Generally, the last two require approaches similar to the first two to provide production information.

RPA calls for inclusion of cost dimensions, in addition to the biophysical production relationships involved in the first two alternatives. This paper will concentrate on modeling the cost dimension of multiresource interactions.

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In choosing between the last two alternative approaches, one is tempted to conclude that both are necessary. The legislative mandate clearly asks for current and anticipated demand and supply information, for which the predictive econometric simulation (3) approach is clearly geared. There are at least three reasons why the operations research approach of optimization analysis is also important:

(1) There appears to be a mandate in the legislation to go beyond prediction to identification of "opportunities" for improving the future situation. This would seem to indicate that both simulation and optimization analyses are called for.[2] If the assessment is to be linked with the RPA program, then it must deal with the prescriptive problem of public land management decisions.

(2) If cost-efficient behavior is not observable for any of the resources involved, then regressed supply functions will not be true marginal cost functions. When predictions of behavior (of land owners/managers) are desired, then the econometric approach is still appropriate. If, however, true cost functions are desired and cost-efficient behavior is not observable, then the cost function must be "calculated" through such means as an operations research model.

(3) Regressing interrelated supply functions that could predict supply-side interactions and trade-offs between different resources is a very difficult task, both in terms of data considerations and of the econometric analysis. Thus, the optimization analysis is often necessary to analyze resource trade-offs and interactions. It will be a useful digression to discuss the difference between single output and joint output analyses of supply.

Define a situation with two inputs and two outputs:

$$0 = f(X_1, X_2, Y_1, Y_2) \qquad (1)$$

where f is an implicit production function, the X's are inputs and the Y's are outputs. Assuming linear forms for convenience, this joint production system (1) implies supply functions of the form:

$$\begin{aligned} S_1:\quad P_1 &= a_1 + b_{11}Y_1 + b_{12}Y_2 \\ S_2:\quad P_2 &= a_2 + b_{21}Y_1 + b_{22}Y_2 \end{aligned} \qquad (2)$$

where the P's are prices of the Y's. Supply shifters are suppressed for simplicity. The cross-supply terms ($b_{21}Y_1$ and $b_{12}Y_2$) appear because of the joint production function assumed. Single output supply functions would look something like:

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[2]Performing every desirable analysis in the world is not feasible; thus, the optimization analysis discussed later is quite simple and makes much use of existing analyses.

$$S_1: \quad P_1 = a_1 + b_{11}Y_1$$

$$S_2: \quad P_2 = a_2 + b_{22}Y_2 \tag{3}$$

where production processes are assumed to be independent; thus, no cross-price terms appear (Henderson and Quandt, 1971). Obviously, these two supply systems imply different equilibria, and the associated cost functions are also different. The single output cost function is (totaling over outputs):

$$\sum_{i=1}^{2} \int_{o}^{Y_i^*} (a_i + b_{ii}Y_i)dY_i = \sum_{i=1}^{2} (a_iY_i + 1/2b_{ii}Y_i^2) \tag{4}$$

Whereas, the joint cost function is:

$$\int_c \sum_{i-1}^{2} (a_i + \sum_{j=1}^{2} b_{ij}Y_i)dY_i$$

where $\int_c$ is the line integral of the system of supply curves between the origin and the (Y) terminal output vector.

By a common theorem on line integrals (Taylor, 1955, p. 437):

$$\int_c \sum_{i=1}^{2} (a_i + \sum_{j=1}^{2} b_{ij}Y_i)dY_i = \underset{\sim}{a}'\underset{\sim}{Y} + 1/2\underset{\sim}{Y}'\underset{\sim}{b}\underset{\sim}{Y}$$

$$= \sum_{i=1}^{2} a_iY_i + 1/2 \sum_{i=1}^{2} Y_i \sum_{j=1}^{2} b_{ij}Y_j \quad , \tag{5}$$

so long as the line integral is independent of the path of integration and thus single-valued.

Economic theory indicates that cross supply terms are symmetrical,[3] because of the absence of an income effect (Henderson and Quandt, 1971, p. 98). Thus, the difference between (4) and (5) is:

$$b_{12}Y_1Y_2 \text{ or } b_{21}Y_1Y_2$$

It is clear that with nontrivial cross-supply coefficients (b_{12} and b_{21}), the potential error in (4) is substantial.

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[3]This condition is necessary for the line integral to be independent of the path of integration and thus single-valued. Also, this symmetry condition implies that supply-side resource interactions are always "mutual." If, for example, timber harvest levels affect other resources, then the converse must necessarily be true.

The sign of the b_{12} and b_{21} is determined by the nature of the joint production function (1) involved. If they are negative, functional supply curves over-estimate joint costs. In a system of n goods, some cross-supply terms might be positive and some negative; in which case, the overall bias would be difficult to predict.

This suggests that functional derivation of supply and demand functions will not result in theoretically tenable results if, in fact, the relevant production system is "joint" and the resulting supply functions have nonzero cross supply terms. The biases derived above suggest that if cross-supply coefficients are close to zero, then the errors involved in functional equlibria will be small.

Before proceeding, it is important to note that the operations research approach does not derive the system of supply functions described in (2), *per se*. Inputs are generally costed rather than outputs. Costs are included for "management prescriptions," which are joint costs associated with an entire vector of outputs. This joint cost is equivalent to (4), because it is the total cost of the output vector with all production interactions already having been accounted for. The use of joint costs does not allow derivation of cost/benefit ratios for each output, but this is impossible anyway. Referring to (2), a change in (for example) Y_1 would cause not only a shift along its own supply function, but also a shift of Y_2's supply function and thus reequilibration of all prices and quantities. This simply reflects the fact that allocation of a joint cost to any individual output is purely arbitrary.

It is also important to note that the operations research analysis would ideally utilize the demand functions (for output benefits) that econometric analyses derive. Demand functions are regressed based on utility-maximizing assumptions on observed data similar to the cost-efficiency assumptions for supply curves. The distinction is that the utility maximizing assumptions concern behavior of consumers and are not directly affected by public ownership of the production unit. The observed data may be distorted by public ownership where equilibrium prices are not charged, but the assumptions of utility maximization concerning the demand curve itself are left intact.

The remainder of this paper will discuss the structure of an operations research analysis that is proposed as one possible approach to modeling resource interactions. The description will begin with a simple description of the types of land management unit optimization models that are either already available or are currently being developed. Then, a simple model structure will be described that can utilize the outputs of the management unit models at the regional and national levels.

LAND MANAGEMENT UNIT OPTIMIZATION

A number of multiresource linear programming models have been used and are being used in forest resource planning (RCS, MAGE5, FORPLAN, and others). A simplified linear programming model considering only two types of land, five management prescriptions, and three resources will be used to illustrate the general idea of how these are structured (D'Aquino, 1974; Kent, 1980).

AN INTEGRATED MODEL FOR THE 1990 ASSESSMENT

The previous section outlined a basic model structure that addresses management unit planning problems. However, the difficulty of scope remains. On the one hand, modeling relatively small areas of land (such as a national forest) is appealing because of the relative detail, resolution, and accuracy that can be achieved. On the other hand, regional and national concerns may be different from local concerns, increasing the desirability of a model which can capture absolute and comparative advantages between smaller land units.

The ideal resolution of this dilemma would be the use of a single national optimization model that is also capable of achieving high levels of resolution and detail. Because this is unworkable at this time, a multilevel modeling approach is suggested here. This approach attempts to combine national and regional discretion, small-scale resolution and detail, and consistency between different levels of planning.

Work by Wong (1980) in U.S. Forest Service Southwestern Region provides an excellent start for the modeling approach suggested here. In general, he proposes that regional and national models should not directly consider land management prescriptions, but rather choose from alternative management plans. These alternatives would be developed at the land unit level for a regional model and similarly at the regional level for the national model. Each alternative management plan might be associated with a different budget (level of investment), a different objective function, or with different policy constraints (such as wilderness emphasis, mandated stewardship-level management intensity, fiber production emphasis, etc.).

Figure 2 portrays the basic structure of Wong's multilevel model. In Figure 2, it is important to note the information carried in the "Alternative Management Plans." Each alternative is specified by all associated resource output levels, some measure of their benefits, and all associated joint costs (budget requirement).

It should be made clear that the ecological production information enters the problem at the first, land-based level. The economic information, especially supply (cost) and demand (benefit) information, can be utilized at all levels, as is analytically appropriate. And, social information can be used to constrain model solutions at any level so as not to violate social concerns. Different types of social impacts apply at different levels of analysis. The model structure depicted in Figure 2 is quite conducive to such a situation.

The National Assessment Multiresource Model (NAMM) proposed for the 1990 Assessment is shown in Figure 3.[4] The lowest level of analysis occurs at the National Forest Level where the Forest System Production Possibilities Generator ($FPPG_{i,j}$) is used to define production possibilities for each forest within each region. In the FPPG, acre by acre land allocations are made for those land units under Forest Service control.

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[4]This proposed approach is evaluated in a staff paper by E. T. Bartlett, "A Conceptual Evaluation of a Proposed National Assessment Multiresource Analysis with Recommended Studies," available from the Rocky Mountain Forest and Range Experiment Station, USDA Forest Service, Fort Collins, Colorado.

This simple model ignores time dimensions and other complexities, such as social impact constraints and nonconstant benefit coefficients. Environmental quality indexes are also excluded from the example. These complexities can be brought into the analysis without major conceptual difficulty--though such a model would be significantly larger (i.e., more rows and columns), and data problems are often encountered with such complexities.

In Figure 1, the major column headings are types of land and/or resources. The X_i's under the two land types are the number of acres allocated to alternative management prescriptions which could be applied in TYPE I (X_1 and X_2) and TYPE II (X_3, X_4, X_5) land.

The timber, wildlife, and forage rows in the matrix represent the resource outputs of this forest system resulting from implementation of the management prescriptions. The land, TYPE I and TYPE II, rows are the inputs (acres) to this "joint production system." K_5 acres of Type I land are available, and K_6 acres of Type II land are available.

The timber output, wildlife output, and forage output rows are the amounts of each of the outputs that are harvested from the forest system. The "Net Ben." row (present value of net benefits) is an objective function which managers might seek to maximize given the resources available and the production relationships involved.

The X's under the major column heading PRODUCTS ($X_{6,7,8}$) are accounting columns which collect and, possibly, transform the outputs into an aggregate output for the area being analyzed.

The A_{ij}'s in columns 1-5 can generally be termed the impacts of the j^{th} management prescription on either the ith row outputs or inputs. For example, $A_{1,1}$ is the output of timber per acre if the first management prescription is implemented on that acre, and $A_{5,1}$ is the amount of Type I land utilized (in this case, one acre). The coefficients in row 10, the "Net Ben." row, describe the change in net benefits if one unit of the j^{th} management prescription or product enters solution. Thus, $A_{10,1}$ is the cost of prescription 1 and $A_{10,6}$ is the benefit derived from one unit of timber output (X_6). K_4 is an upper limit on the amount of money to be made available for managing the area. K_7 through K_9 are output targets for timber, wildlife, and forage.

The solution to this maximization problem simultaneously determines the regime of management prescriptions applied to different land areas and product mixes that maximize the given objective function.

	Type I		Type II			Products			Constraint type	RHS
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8		
Timber	$A_{1,1}$	$A_{1,2}$	$A_{1,3}$	$A_{1,4}$	$A_{1,5}$	$-A_{1,6}$			=	$K_1 = 0$
Wildlife	$A_{2,1}$	$A_{2,2}$	$A_{2,3}$	$A_{2,4}$	$A_{2,5}$		$-A_{2,7}$		=	$K_2 = 0$
Forage	$A_{3,1}$	$A_{3,2}$	$A_{3,3}$	$A_{3,4}$	$A_{3,5}$			$-A_{3,8}$	=	$K_3 = 0$
Budget	$A_{4,1}$	$A_{4,2}$	$A_{4,3}$	$A_{4,4}$	$A_{4,5}$				≦	K_4
TYPE I	$A_{5,1}$	$A_{5,2}$							=	K_5
TYPE II			$A_{6,3}$	$A_{6,4}$	$A_{6,5}$				=	K_6
TIMBER OUTPUT						$A_{7,6}$			≧	K_7
WILDLIFE OUTPUT							$A_{8,7}$		≧	K_8
FORAGE OUTPUT								$A_{9,8}$	≧	K_9
NET BEN.	$-A_{10,1}$	$-A_{10,2}$	$-A_{10,3}$	$-A_{10,4}$	$-A_{10,5}$	$A_{10,6}$	$A_{10,7}$	$A_{10,8}$		

Figure 1.--A simple resource allocation model where X_1 and X_2 are the number of acres in Type I land allocated to alternative management prescriptions: X_3, X_4, X_5 are the number of acres in Type II land allocated to alternative management prescriptions; X_6, X_7, X_8 are timber, wildlife, and forage products, respectively; the A_{ij} are production coefficients; the $A_{10,j}$ are the objective function coefficients; and the K_i are the right hand sides (RHS).

Figure 2.--Multilevel model of the Forest Service planning process (from Wong 1979).

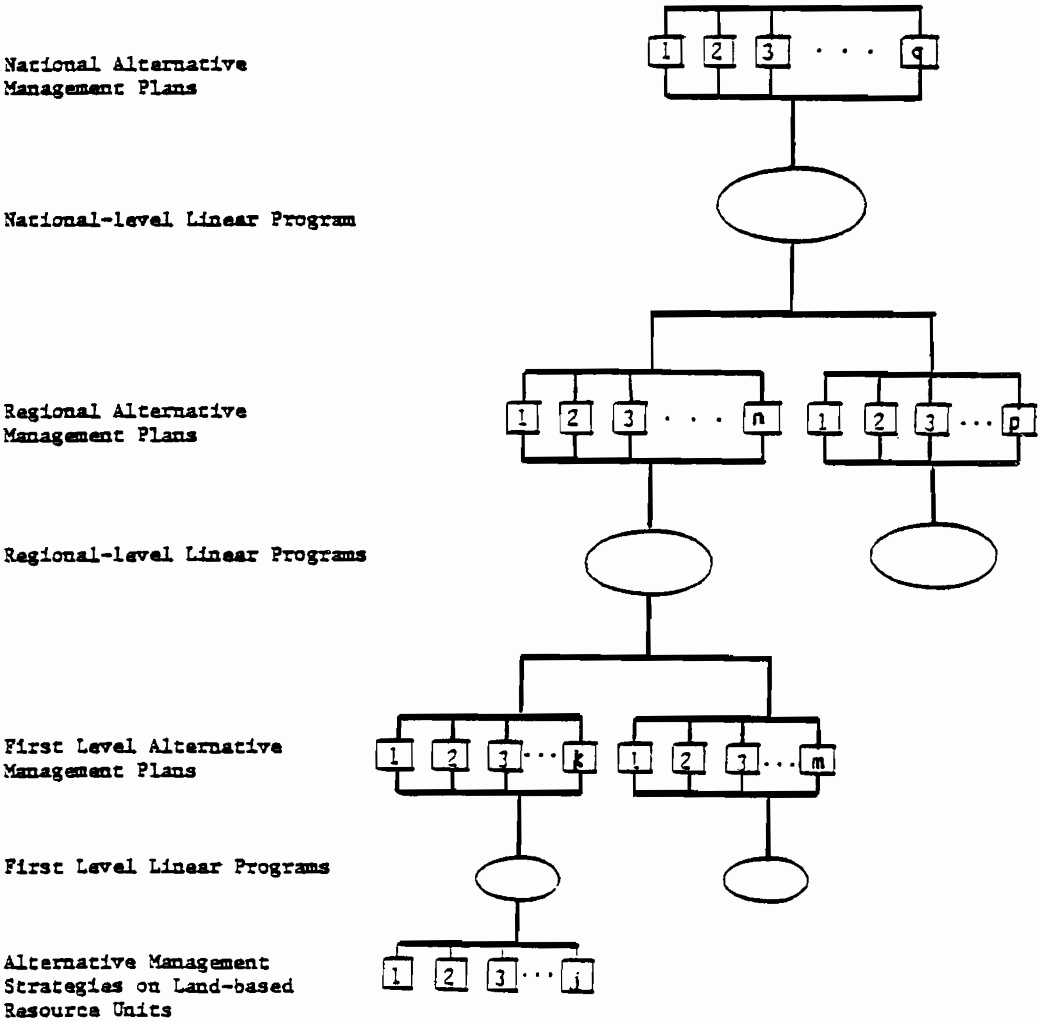
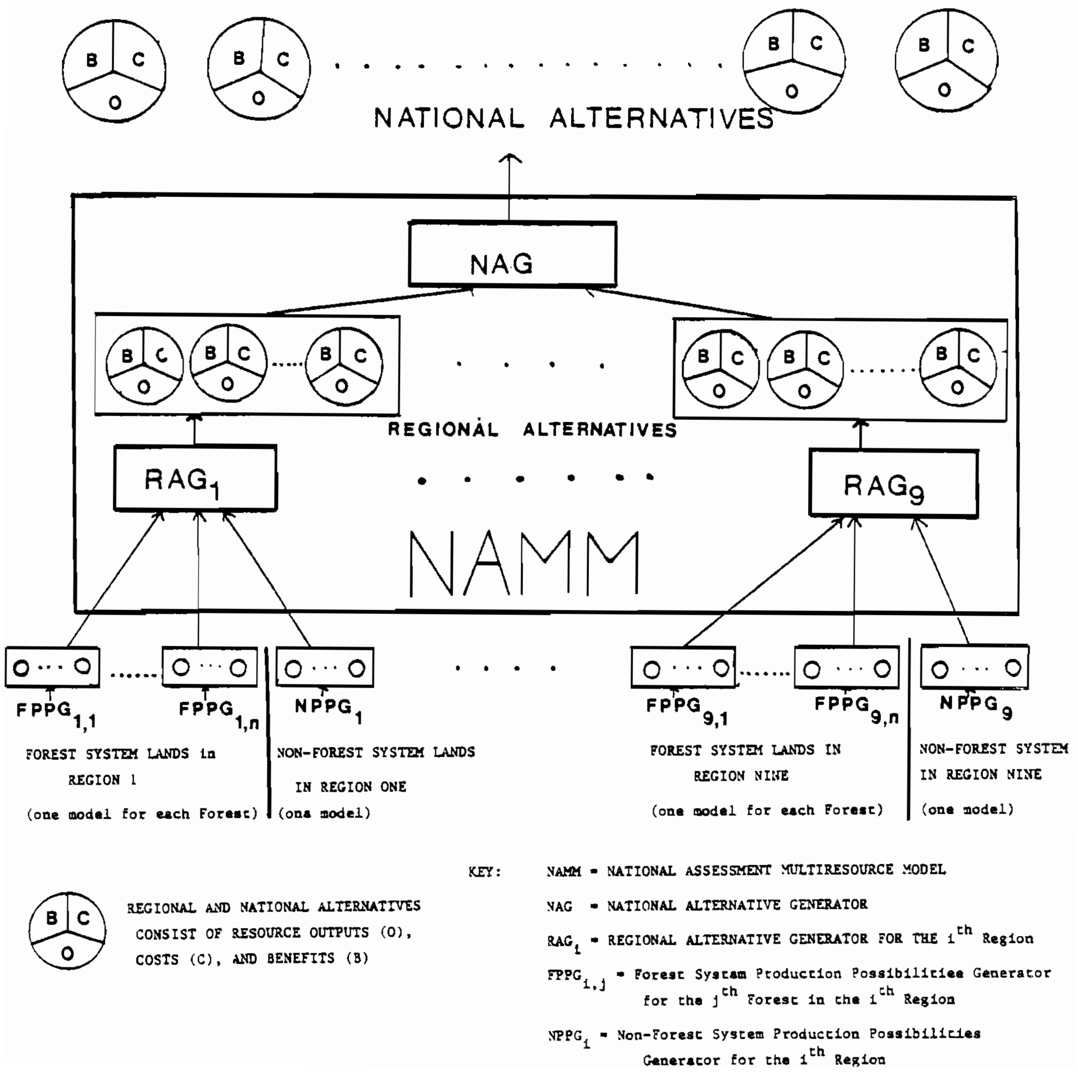


Figure 3.--Multilevel modeling structure proposed for the 1990 Assessment analysis.



Because specific land allocations on lands not in the National Forest System are not within the control of the Forest Service, it seems reasonable that the modeling effort on these lands for the 1990 Assessment need not involve the detail and level of resolution that the FPPG models facilitate. One model for each Forest Service Region lands not in the National Forest System, $NPPG_i$, would construct a general "picture" of opportunities on these lands. Similar to FPPG, the NPPG would allocate land units to management prescriptions, but on a much broader scale. The FPPG and NPPG models are of the type depicted in Figure 1.

Forest system and nonforest system lands are treated separately until the regional model. Joint strategies between National Forest System and other ownerships (other federal, states, and private) within each region would be analyzed in the Regional Alternative Generator models, RAG_i. The inputs to the regional models from the FPPG's and from the NPPG would be resource output levels (including environmental quality indices), operating costs (budget requirements) associated with selected management prescriptions, and benefit measures associated with the output levels. In many cases, the benefit measurements would be made most readily at the regional level.

Regions are treated separately until the national model. Joint strategies between regions would be analyzed in the National Alternative Generator, NAG. The inputs to this National model from each regional model would also be resource output levels (including environmental quality indices), operating costs (budget), and benefits. Acre-by-acre land allocations occur only within the Forest System Production Possibilities Generator, $FPPG_{i,j}$ and the Non-Forest System Production Possibilities Generator, $NPPG_{i,j}$.

As will be seen, the National and regional models are relatively simple and could be rerun quickly and inexpensively at any time during the decisionmaking process. The Production Possibilities Generators (both FPPG and NPPG models) are much more complex and expensive to run. This suggests that a carefully planned, systematic method of using the FPPG and NPPG models in generating alternatives is required, so that it only has to be done once.

The National model assumes production independence between regions, and the regional models assume production independence between lands within and not within the National Forest System. That is, management actions in one land unit are assumed not to affect the production possibilities in another land unit. This may not actually be the case. For example, migrating bird populations might be enhanced through coordinated habitat management on a given flyway. The magnitude of potential errors that are to be expected from this simplification is not known at this time.

The suggested models for the FPPG are the FORPLAN models currently being developed in the USDA Forest Service Land Management Planning effort. If private lands are to be treated (hypothetically) as choice variables, then the suggested models for the NPPG are revised versions of the National Interregional Multiresource Use Model (NIMRUM) regional models (Ashton et al., 1980). If private lands are not to be treated as choice variables, then a predictive model would be appropriate for the NPPG's. Validation of the production information in the FORPLAN and (possibly) NIMRUM models is a high priority research problem because of the importance of the information in the NAMM structure as a whole. The model structure for the RAG's and the NAG would essentially be the same, and this structure remains to be developed fully.

Figure 4 depicts the linear programming matrix of a very simple version of a National model. In this example, only two regions, two alternatives, and three products are included. Also, only one time period is included, and embellishments such as regional targets are not included. Expansion beyond the dimensions of this simple example is straightforward.

In Figure 4, X_1 through X_8 are 0-1 variables representing selection or rejection of an alternative output vector (with associated benefits and costs) for a given region and ownership. For example, X_1 represents selection or rejection of the entire output vector $A_{1,1}$; $A_{2,1}$; and $A_{3,1}$ in Forest System Region 1. All of the matrix below the NET BEN. (objective function) row constrains the X_1 through X_8 so that each of them is between 0 and 1, and so that only one alternative can be selected for each region and ownership. Rows 5 through 7 set national "targets" on the three outputs. Row 4 places a budget constraint on the selection of alternatives, and row 8 is the objective function to be maximized.

Because this is a linear programming model instead of a discrete optimization model, X_1 throught X_8 may actually take on solution values between 0 and 1 but not equal to either. For example, X_1 and X_2 in Figure 4 may solve with values of 0.6 and 0.4, respectively. This is interpreted as a partial acceptance of each alternative, the combination of which may or may not be feasible. This may suggest the construction of a new alternative that is subjectively constructed from X_1 and X_2, based on the solution values. No assurance can be made, however, that this new alternative will be completely accepted. Its presence may actually cause changes in the solution values of any or all other variables as well. Resolution of this problem/question is an important research need in the development of NAMM. The use of zero-one programming would avoid this problem, but the partial acceptance of alternatives may prove to be valuable information.

If the model depicted in Figure 4 were a regional model, then instead of "Forest System Regions," the model would have, within the Forest Service region being studied, each of the National Forests and a unit for land outside the National Forest System. Referring back to Figure 1, the output vectors in a given regional model would be the solution values of the products (X_6, X_7, and X_8 in Figure 1) in the lowest level models (FPPG, NPPG). For example, the $A_{1,1}$; $A_{2,1}$; and $A_{3,1}$ in Figure 4 would be the first alternative solution values of X_6, X_7; and X_8 in Figure 1 for the first National Forest.

Finally, this modeling structure need not be static. The choice variables at all levels can be linked to different time periods, and the solution will thus include output-mix scheduling choices. The linear programs (FORPLAN) being developed in the Forest Planning effort are so structured. The conversion of NIMRUM to handle scheduling problems (and the desirability of such conversion) is a possibility, but may not be required, given the general nature of information required for lands not in the National Forest System.

Figure 4.--A simple NAG model, where the X_1 through X_8 are 0-1 variables representing selection or rejection of an output vector $A_{i,1}$ through $A_{i,8}$ (i=1,3) respectively, the $A_{8,j}$ are the objective function coefficients, and the K_1 through K_7 are right hand sides (RHS).

	Forest System Region 1		Non-Forest System Region 1		Forest System Region 2		Non-Forest System Region 2		Products			Constraint type	RHS
	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}		
Timber	$A_{1,1}$	$A_{1,2}$	$A_{1,3}$	$A_{1,4}$	$A_{1,5}$	$A_{1,6}$	$A_{1,7}$	$A_{1,8}$	$-A_{1,9}$			=	$K_1=0$
Wildlife	$A_{2,1}$	$A_{2,2}$	$A_{2,3}$	$A_{2,4}$	$A_{2,5}$	$A_{2,6}$	$A_{2,7}$	$A_{2,8}$		$-A_{2,10}$		=	$K_2=0$
Forage	$A_{3,1}$	$A_{3,2}$	$A_{3,3}$	$A_{3,4}$	$A_{3,5}$	$A_{3,6}$	$A_{3,7}$	$A_{3,8}$			$-A_{3,11}$	=	$K_3=0$
Budget	$A_{4,1}$	$A_{4,2}$	$A_{4,3}$	$A_{4,4}$	$A_{4,5}$	$A_{4,6}$	$A_{4,7}$	$A_{4,8}$				$\leq$	K_4
TIMBER OUTPUT									$A_{5,9}$			$\geq$	K_5
WILDLIFE OUTPUT										$A_{6,10}$		$\geq$	K_6
FORAGE OUTPUT											$A_{7,11}$	$\geq$	K_7
NET BEN.	$-A_{8,1}$	$-A_{8,2}$	$-A_{8,3}$	$-A_{8,4}$	$-A_{8,5}$	$-A_{8,6}$	$-A_{8,7}$	$-A_{8,8}$	$A_{8,9}$	$A_{8,10}$	$A_{8,11}$		
	1	1										=	1
0-1			1	1								=	1
Model					1	1						=	1
Constraints							1	1				=	1

ADVANTAGES AND DISADVANTAGES OF THE NAMM STRUCTURE

Advantages:

(1) It can accommodate decisionmaking at a number of different levels. This is important when attempting to account for considerations (such as social impacts) that are not conducive to aggregation into a national analysis. Use of this structure is also useful in capturing regional comparative advantages.

(2) It can incorporate, as the state of the art allows, ecological, economic, and social information.

(3) It is of very workable size and complexity at the regional and national levels. This is the case because the choice variables at these levels are defined as discrete alternatives. In the national model, for example, with 9 Forest Service Regions and 10 alternatives per Region, only 90 choice variables are implied.

(4) It solves the problem of disaggregating national analysis results across smaller land units.

(5) It avoids problems of inconsistency between levels of analysis which would occur if these analyses were performed independently.

(6) It provides for production possibilities analysis to occur at the lowest level where a relatively high degree of resolution is possible, while at the same time preserving discretion at higher levels of decisionmaking.

(7) It can utilize existing or soon-to-be-available, production-oriented models (FORPLAN and NIMRUM).

(8) The discussion above describes an assessment analysis which uses a number of supporting analyses, namely:
   (a) Economic analysis on joint costs and output benefits.
   (b) Ecological analysis for the production input data in the Production Possibilities Generators (such as FORPLAN and NIMRUM).
   (c) Social impact analysis at various levels of resolution.
   (d) The actual generation of Production Possibilities with models such as FORPLAN and NIMRUM.

Clearly, the viability and reliability of NAMM is affected directly by the quality of these supporting analyses.

The operation of NAMM is not completely dependent on any of these analyses, however--there are contingencies if any of these "fail."

For example:

(1) If benefit measures are not available for resource outputs, then NAMM will still be able to generate alternative (opportunities) on the basis of cost minimization, constrained single output maximization or other objective functions.

(2) If the ecological analysis is unable to improve the production data currently available, then the existing information can be used as the best available.

(3) If the PPG's (such as FORPLAN and NIMRUM) are not available in a credible form, then the production possibilities could be generated in a less rigorous manner. For example, an interdisciplinary team approach could be utilized to develop production possibilities on Forest System lands by each Forest Supervisor's staff.

In all such contingencies, the failure of a supporting analysis would weaken the results of NAMM, but in all cases, NAMM will be capable of utilizing the best available information.

Disadvantages:
(1) Limiting the choice variables at the regional and national levels to selection from a finite number of alternatives may cause the analysis to overlook desirable options that are, in fact, feasible.
(2) In limiting most of the production possibilities analysis to the lowest level of analysis, some interaction effects between land units may be ignored. Examples of these effects are (1) enhanced migratory bird populations resulting from coordinated habitat management on a given flyway, and (2) downstream water quality effects resulting from timber harvesting.

Evaluation and amelioration of these disadvantages is the primary research need in developing the NAMM structure. Otherwise, research is needed to develop the supporting ecological, economic, and social analyses.

CONCLUSION

Previous national assessment analyses in the United States have tended to analyze one resource at a time and have tended to be predictive. One important exception was the NIMRUM effort attempted in the 1980 RPA Assessment Analysis of "Multiresource Use Interactions." The NAMM model structure could be regarded as an extension or development of this effort--an extension oriented toward simplification and increased workability. NAMM leaves the detailed problems of land allocation and management practice scheduling to the lowest land unit level of analysis. At the regional and national levels, the point of focus is the problem of selecting the output mix. By limiting the regional and national analyses to this problem, the models at three levels are reduced to workable size and complexity, yet a considerable degree of discretion at these higher levels of analysis is preserved.

Finally, this paper has concentrated on a proposed prescriptive modeling approach. This is not to be interpreted as preempting predictive models for national assessments. On the contrary, assessment of renewable resource trade-offs has both predictive and prescriptive elements, and both types of analysis are necessary.

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TIMBER INVENTORIES: AN UNDERUTILIZED RESOURCE THAT COULD SUBSTANTIALLY IMPROVE TIMBER SUPPLY PROJECTIONS

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Abstract.--Timber supply projections frequently use assumptions which are unrealistic. Many of these are based on "common wisdom," in spite of the fact that timber resource inventories are available that could be used to strengthen and improve these assumptions. A study is described which tests commonly used assumptions against those based on resource inventories. Preliminary results indicate in one test of two assumptions of age of timber harvested that differences of 44 percent in inventory volume in 30 years would result. Suggestions are made for closer ties between "inventoriers" and "modelers."

The number and sophistication of models capable of projecting timber resources into the future is increasing rapidly. The effort going into model development and refinement, however, has not been matched either by a similar effort to gain a better understanding and appreciation of the existing resource data available for input into the model or by identification of new resource data needed to take advantage of the increasing capability of models. If a model does not build solidly from a foundation of resource data that realistically portrays what is on the ground and what might happen to it, the results generated by the model may well be deceptive. Model building and data gathering have been independent, unrelated functions—this should change if we are to improve timber supply projections. Currently, at the Pacific Northwest Forest and Range Experiment Station, we are working closely with modelers to integrate these functions.

Two decades ago, the Oregon Legislature commissioned a consulting forester to forecast timber supply for the State. He presented a convincing case for a future with increasing timber output. He did this by applying a normal yield table—which is developed by searching out the best stocked stands—to all acres. He ignored the fact that some acres don't regenerate, some conifer acres come back to hardwoods, and some owners don't want to harvest their timber. As a consequence some Oregonians were lulled into complacency for 10 years, time that could have been far better spent in planning on how to offset the timber supply shortages that we see today.

Even if the more sophisticated models of today had been used to make that projection, the results still would have been equally wrong. An example is a timber supply projection just completed for the Northwest. The projection includes a modeling of economic supply and pretty much represents the state of the art. Some of the social and biologic assumptions used were:

1. Private owners respond fully to market forces.
2. All timber stands were even-aged and all timber was harvested by clearcutting.

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3. Oldest stands were harvested first.
4. Industrial hardwood acres were converted to conifer-growing lands at a rate of one-third of the outstanding hardwood per decade.
5. Nonindustrial hardwood acres were not converted.
6. Nonindustrial acres were assumed to be lost to the inventory at a rate of 1 percent per year.
7. All nonindustrial timberlands would be intensively managed.
8. Regeneration would occur within 5 years of harvesting.
9. All stands would be regenerated to Douglas-fir.

Very few, if any, of these assumptions are more than conventional wisdom. Some relate poorly to the biologic, ecologic, economic, and social dynamics of the real forest and the industry we are trying to model. Remeasurement data from permanent inventory plots show that most of the assumptions are not realistic. It makes little difference that the assumptions are well displayed--if they are baseless. Few of the users of these projections will be able to appraise the impact of such assumptions on the projections.

The Renewable Resources Evaluation Project (formerly Forest Survey) of the Pacific Northwest Forest and Range Experiment Station is the principal supplier of resource data used as input to practically all of the timber supply studies made for the Northwest. Our research program includes developing methodology to fully utilize available resource data, and to improve the design of inventories to meet the increasing flexibility and capability of new and changing models.

With the help of Phil Teddar of Oregon State University, I am examining three questions that relate to better use of available resource data. The first question examines a procedure commonly used in all even-aged projection models used in the Pacific Northwest. This is the assumption that all stands are harvested on the basis of oldest first. If the oldest first assumption is not correct we may be unduly optimistic about growth. Figure 1 shows the inventories generated in 30 years by size and numbers of trees varying only the harvesting assumptions. The projections started from the same inventory and removed the same volumes annually. In this example, generated through use of a stand projection model rather than an even-age model, an assumption of harvest of largest diameter tree class first is compared to a harvest assumption using the actual tree harvest from reinventoried plot data. The assumption of largest diameter tree harvesting generates an inventory in 30 years that has 44 percent more growing stock, is growing 46 percent faster, and has trees no larger than 14 inches in diameter when compared to the inventory generated using actual tree diameters harvested.

Remeasured plot data for western Oregon will be used to determine if the assumption of oldest first harvesting is correct. Our inventory design consists of a grid of sample plots permanentely located and referenced. Western Oregon was inventoried in 1961-62 and reinventoried in 1973-76. Data from the original inventory were modified as necessary so as to be directly comparable to reinventory measurements. The change data from the two inventories will provide us with firm input on age of stands harvested. We are also finding that considerable timber harvesting is obtained from partial cutting. We will include this in our testing of harvesting assumptions.

For many years, the nonindustrial owner class identified in Forest Service studies of timber supply has been criticized as a meaningless catch-all; but most timber supply projections still use this owner class in their projections. Our second question then is to determine if, using available survey data, more meaningful owner classes can be developed and what difference this would make in timber supply projections. We determined that on the basis of size of timberland holdings, proportion of manageable forests owned, and timber harvesting characteristics, three owner classes could be defined. We identified: farmer-owned, miscellaneous owners, and nonfarm corporate- and tree farmer-owned. Table 1 shows the difference between these owner classes by size of holding, with forest industry and corporation and tree farmers having the larger size ownerships; farmers and miscellaneous owners the smaller holdings. Miscellaneous owners are the only owner class that have substantial holdings in tracts 10 acres or less in size. Table 2 shows the proportion of manageable forests by ownership classes with forest industry and corporate and tree farmers being reasonably alike, especially in over 5,000-acre holdings. As suggested by owner motivation studies, miscellaneous owners and farmers have the lowest proportion of manageable forests. Table 3 shows that forest industry, farmers, and corporations and tree farmers favor clearcutting. Miscellaneous owners clearcut little but partial cut substantially--possibly in order to maintain esthetic values. Farmers both clearcut and partially cut extensively. Farmers evidently are used to harvesting crops, whether agricultural or timber. Our data show that the disaggregated owner classes seemed more alike than the single nonindustrial owner class they had previously been grouped into. We will test whether use of these classes will produce different projections of timber supply.

The third part of our study is to make a "base run" that portrays the future as it may be if present trends continue. We felt this was necessary as our reinventory data permits us to include in our projections a better appreciation of the full range of biologic, economic, and social considerations that impact on timber supply projections.

Among the elemental items we are looking at is the impact of *Phellinus weirii*, a common root rot, which results in loss of forest area to conifer tree production. This is a disease that impacts young-growth Douglas-fir and has serious implications as more of the forest area is regenerated to Douglas-fir. Currently, we estimate as much as 13 percent of our forest survey plots in Douglas-fir type are infested with this root rot.

Remeasured plot data also provide us with a much better basis for determining trends in timberland ownership and loss of forest land to other uses (Table 4). The most significant shift in timberland area was 279,900 acres from nonindustrial to forest industry ownership. This amounts to an increase of 20,300 acres per year, an addition of almost 1 percent of the industrial timberland base. Timberland loss from nonindustrial private owners to nonforest uses are substantial. Approximately 222,000 acres were converted, mainly to pasture but some to urban development. Equally important is the productive capactity of the timberland involved. Timberland shifted to industry was of fairly high site but timberland converted to other land uses was of low quality--in some cases sufficiently low in productivity that its loss has little impact on timber production. Few projections take into account these types of shifts.

We will also include in the base run, based on remeasured plot data, what happens to forest land after timber harvesting. Some conifer land comes back to hardwoods, some to conifers with varying amounts of stocking, and some remains nonstocked because of "tough sites" or deer or rodent damage.

Table 1—Private timberland by owner class and size of holding in western Oregon, 1975

Owner class	Size of holdings (in acres)				
	1-10	11-100	101-1,000	1,001-500,000	>500,000
	- - - - - - - - - - - - - Percent	- - - - - - - - - - - - - - - - - - -			
Farmer	2	25	59	14	*
Miscellaneous	17	30	47	6	*
Corporations and tree farmers	1	9	22	68	*
Industry	0	0	0	69	31

*Not observed in sample.

Table 2--Proportion of total timberland in manageable stands by owner class and size of holding in western Oregon, 1975

Owner class	Size of holdings (in acres)					
	1-10	11-100	101-1,000	1,001-500,000	>500,000	All holdings
	Percent					
Farmer	--	54	53	--	--	54
Miscellaneous	57	64	65	--	--	63
Corporations and tree farmers	--	--	57	83	--	69
Industry	--	--	75	75	82	80

Table 3—Proportion of softwood sawtimber stands clearcut and partially cut by owner class between 1965 and 1975 in western Oregon

Owner class	Clearcut	Partially cut	Total
		-Percent-	
Farmer	14	16	30
Miscellaneous	4	13	17
Corporations and tree farmer	12	20	32
Industry	20	11	31
All classes	17	12	30

Table 4—Net change in timberland by owner class 1962 to 1975, western Oregon

Owner class	Shifts of timberland between owners	Timberland conversion		Total change in timberland	Total change
		To nonforest	From forest		
	Acres				
Industry	+279,900	-36,600	+22,000	+262,300	+19,400
Nonindustrial	-251,300	-222,400	+28,000	-445,700	-33,500

We can also appraise and include in the base run the economic operability of timber stands. We have developed a model for determining cost of timber extraction on survey plots. Some areas, because of low stocking, difficult slopes, or size of timber, do not develop positive stumpage values. With current or projected stumpage prices, we can identify the timber not economically available.

These are some of the considerations we will be testing against more commonly used assumptions. Some may drop out as having little impact on supply, and some may prove to be of real significance.

We have one other test underway. We have found that the uneven-aged stand projection model (TRAS) commonly used by the Forest Service for the 1980 RPA supply projections sometimes doesn't produce reasonable answers. We became aware of this in using TRAS to update inventories where the updated inventories were widely divergent from reinventories. Since future plans are to continue to use TRAS in the ponderosa pine region of Oregon and Washington and in the Rocky Mountain region we decided to test TRAS as a projection model.

A reinventory of part of eastern Oregon allows testing TRAS to determine if it will reliably update an inventory to the date of the reinventory. We plan to use TRAS to project the original (1962) inventory for central Oregon to the date of the reinventory (1977). If the updated inventory and the reinventory are not reasonably comparable, we will make a sensitivity analysis to determine which of the model's dependent variables, including radial growth, mortality, or timber harvest, are most critical to obtaining better estimates. We anticipate that results from this testing will help us strengthen our modeling of uneven-aged stands.

We are continually modifying our inventory design to provide information of more value. Our permanent inventory design allows identification of trends invaluable to "modelers." We have modified our inventory plot design to identify management opportunities on operational size tracts of land. Our inventory design of 9 years ago obtained all timber resource data from 1-acre-size plots. From these plots, we developed inventory statistics and made estimates of treatment opportunities based on plot stocking. We felt, however, that the 1-acre-plot size was too small to identify operable treatment opportunities. Low stocking might not indicate a realistic planting opportunity as the plot might be surrounded by old growth. Similarly, a 1-acre tract of old growth surrounded by reproduction might not represent a harvesting opportunity. Consequently, we expanded our plot size to 10 acres to identify realistic and operational treatment opportunities.

To do a better job of projecting timber supply, I would make the following suggestions:

1. The specialized forest resource data needs of projection models should be recognized, and that "inventoriers" and "modelers" should work together from the onset to obtain necessary and realistic inputs, whether from existing inventories or in design of inventories.
2. "Modelers" and other specialists in various related fields, such as disease and insect research, silviculture, mensuration, ecology, and economics, should work together to develop and provide input necessary to supply projections.

CONSIDERING THE PROBLEMS, HOW FAR HAVE WE COME (OR YET TO GO) IN ADEQUATELY MODELING LONG-TERM TIMBER SUPPLY RESPONSE?--DISCUSSION

Darius M. Adams[1]

The "long term", in the context of timber supply, connotes a period of sufficient length such that the land area devoted to timber production, the form and intensity of silvicultural treatment, the forest investory, and the harvest are all decision variables. A model of long term supply must explain each of these decision elements in a manner consistent with the biological and behavioral characteristics of the forest and owner under study. Restricting attention exclusively to private ownerships in the United States, the past decade has witnessed important advances in models of long term harvest and inventory, given externally generated assumptions on land area and shifts in management intensity. This has added measurably to our knowledge of the physical potential of private lands to supply timber in the long term. Unfortunately, however, these models have not proved to be equally powerful in explaining the harvest behavior of all private owner groups in all regions, nor has much headway been gained in modeling the land area and management intensity elements. As a consequence, my response to the question posed to this panel must be that long term supply models have come only a modest distance and have a long and difficult journey ahead. The following sections discuss progress to date and remaining problems in each of the four major components of long term private timber supply in U.S. forest sector models.

LAND AREA

Current U.S. forest sector models do not provide endogenous projection of the land area in private ownership that is devoted to timber production. These projections are developed externally, usually by analyses of historical trends with a large dose of analyst judgement. To date few attempts have been made to develop projections that go beyond these traditional approaches. The impediment to further progress is not an absence of theories of long term land use. Economists have addressed this issue for at least the last two centuries. Rather, it has proven extremely difficult to translate theory into empirically testable forms. There appear to be two major problems. First, data on private land uses is collected at irregular intervals (roughly every ten years) and is subject to considerable measurement error. The disposition of land withdrawn from forest production over a given time interval, or its use prior to forestation, is generally not known or is not consistently identified in surveys. The returns and costs of competing land uses, which are critical to any attempt to implement a rent-based theory, are generally not available or available only in imperfect form. Second, economic theories are, in a sense, too simple. They concentrate on a single optimizing objective (such as land rent) and do not recognize other owner objectives or characteristics that may alter observed use shifts from the economic optimum.

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Foresty, of course, is not alone in its concern for projecting future land areas devoted to various uses. Recent efforts by agricultural economists to model land shifts in and out of cultivation may offer some useful guides for future work in forestry (see National Agricultural Lands Study, 1981). These studies have, like their forestry counterparts, relied heavily on an assessment of physical capabilities and past trends. They go further, however, by basing the extent of projected area changes in part on an analysis of relative net returns in alternative uses. Whatever form future research may take, it should be recognized that the basic land use decision and the management intensity decision (see discussion below) are not independent. This is clear in the context of a rent theoretical approach, since the returns anticipated from land used for forest production will depend on the anticipated intensity of forest management in the same way that returns from agricultural use will depend on the crop and cropping methods employed (see Schenarts, 1981, for discussion and examples of this point).

INVENTORY PROJECTION

In many respects, the timber inventory projection system is the core of a long term timber supply model. It must provide an accounting system for tallying changes in the inventory due to harvest and area change and must be able to reflect, in a manner that preserves some biological realism, changes in the intensity of forest management on land in forest production. In addition, because forest sector models deal with very large land areas, it must utilize a system that is biologically reasonable for aggregating basic inventory data and as well parsimonious in its time and computational requirements.

Of the four major components of long term supply modeling, timber inventory projection techniques are the most advanced. In addition to numerous systems developed for special applications, three fairly general systems--TRAS (Larson and Goforth, 1974), STEMS (Lundgren and Essex, 1979), and TREES (Tedder et al., 1980)--are also available. These general systems vary markedly in the details of their methodologies and in the degree to which they fulfill the above noted requirements for use in long term supply modeling. For the past decade, TRAS has been used by the U.S. Forest Service in its forest sector modeling efforts. While it has proven to be computationally efficient, it has only very limited capabilities to model shifts in management intensity (see the paper in this symposium by Pierson). It has also been employed with an aggregation system that makes identification of the impacts of shifts in land area extremely difficult. As reported elsewhere in this symposium (see papers by Adams and Haynes and by Tedder), research is now under way to develop a new, hybrid system, employing elements of all three general systems to overcome these problems.

HARVEST

Recent forest sector models in the U.S. have employed two distinctly different approaches to modeling harvest from private lands. In the first, harvest is viewed as a stock adjustment process depending on the current price of timber and the current costs of holding timber inventory (see, for example, Adams and Haynes, 1980). Intertemporal strategies for allocating cut, and hence expected future costs and returns, are ignored. Relations are fit by econometric techniques using historical data on cut, price, and inventory (where holding costs are presumed proportional to inventory). In the second approach (see work by Berck, 1979 and Rahm, 1981), harvest is determined for each of several periods over a planning horizon using a harvest scheduling algorithm. In the study by Rahm (1981), for example, the ECHO algorithm with present net benefits as the objective function is employed. In this method, the returns from harvesting timber in any given period are weighed against the opportunity costs of earlier or later disposal.

The econometric approach suffers from a relatively weak theoretical base and from the scarcity and questionable quality of historical harvest and inventory data. It has proven unable to explain observed harvest behavior in regions where private stumpage markets are of minor importance or for owner groups that have complex harvest objectives. The harvest scheduling approach, by comparison, entails a very strong assumption of intertemporal efficiency, has been tested against actual historical behavior in only one instance, has not been employed to examine more than one private ownership group in a region, and presents some problems in linkage with the market elements of a forest sector model. Both models ignore non-market returns from forest ownership.

Harvest behavior on non-industrial private forests presents the greatest problems for both theory and modeling. Econometric time series models do poorly in explaining historical harvest for this owner group (in some regions), while harvest scheduling models have yet to be implemented for this group alone. This is also an extremely heterogeneous group, with apparently diverse ownership objectives. Recent research by Binkley (1981) and Knapp (1981) utilizing cross-sectional data, however, appears to offer some promise of more powerful models of non-industrial harvest. Proceeding from the assumption that owners attempt to maximize combined market and non-market returns from their lands, Binkley and Knapp derive empirically testable equations to describe harvest behavior. Application of their approaches has been limited to a few areas in the northeastern U.S., where detailed data on harvest activity and owner characteristics have been collected. In my view, their results to date warrant extension of data collection efforts to other regions with large concentrations of non-industrial forest ownership. At the same time, application of the harvest scheduling approach should be extended to address (separately) both industrial and non-industrial owners in those regions where it has already been employed. Efforts should also be made, following Berck's (1979) approach, to test the method against historical data in several regions for both industrial and non-industrial owners.

MANAGEMENT INTENSITY

Private owner decisions on the intensity at which to manage their forest lands are investment decisions. Theories to explain this behavior are abundant in economics, but, like the land area element noted above, they are difficult to translate into testable form and usable data are scarce. As a consequence, most long term supply projections in the U.S. have simply assumed rates of movement among various management intensity classes, where this issue was considered at all (but see the paper by Lyon and Sedjo in this symposium for an approach with management intensity endogenous). In the 1980 Forest Service Timber Assessment (U.S. Forest Service, 1980), an attempt was made to internalize the intensity decision on the assumption that private owners seek to maximize the present value of returns from their forestry activities. The following itemization of problems encountered in this approach also serves to indicate areas in which further research is needed.

(1) Maximization of the present value of net returns (soil rent or some similar measure) is not the sole objective of management or determinant of management intensity, particularly on non-industrial lands. A more comprehensive, flexible theory is needed.

(2) Data against which models may be tested are limited.

(3) Assuming the propriety of some form of present value model, price and cost expectations structures of owners are unknown and, given the lack of data, may be nearly impossible to determine on an empirical basis.

(4) It is clear that not all treatment opportunities with positive present value available to private owners will be undertaken in any given year or period. This may imply the impropriety of a present value model or indicate the significance of various constraints on owner investment, such as the availability of capital or other inputs, the level and nature of which need further clarification.

(5) Once an investment (silvicultural practice) is initiated, it need not be continued if prospects for economic gain deteriorate or if ownership changes. This suggests the need to continuously monitor areas allocated to all management intensity categories in an investment model, with the option of shifting categories at any (biologically feasible) time.

(6) Public subsidy of forestry investments is endemic in the U.S. Any efforts to model behavior using historical data must, therefore, consider the effects of these inducements.

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PART IV

APPROACHES TO MODELING DEMAND AND INTERNATIONAL TRADE COMPONENTS

THE DATA RESOURCES, INC. APPROACH TO MODELING DEMAND IN THE SOFTWOOD LUMBER AND PLYWOOD AND PULP AND PAPER INDUSTRIES

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ABSTRACT

The Forest Products Group of Data Resources, Inc. has developed fully integrated econometric models of the North American solid wood products industry and the international pulp and paper industry. This paper outlines the general approach used by the Forest Products Group for the demand sectors of the models. The methodology for estimating end-use demand (or consumption) is discussed, using the North American Softwood Lumber and Plywood Model (FORSIM) as an example. The functional form of the end-use demand equation is developed where volume of wood per unit of end-use activity is a function of price substitution, income effect, and technological change. Trade sector methodology is also discussed using the International Market Pulp Model as an example. The functional form of the export share equation for major pulp exporting countries is developed where share is a function of relative capacity available for export and relative variable production costs.

Introduction

The Forest Products Group of Data Resources, Inc. has constructed econometric models representing the softwood lumber, softwood plywood, and pulp and paper industries. Each model is a closed microeconomic representation of the respective industry. A user is required to input exogenous assumptions that indicate the level of macroeconomic activity (e.g., housing starts, industrial production) and inflation projections for manufacturing and capital formation costs. The models translate these economic assumptions into an equilibrium solution of product demand, product supply, and prices. Over a long-term forecast the models have the ability to adjust capacity regionally, based on profitability criteria, in a form that is consistent with classical investment theory.

In this paper we will present the methodology used to construct the demand section of the DRI Forest Products Models. The demand section of each model includes the direct calculation of end-use demand; the distribution of this demand between producing countries and regions (market share section); and adjustments to customer-dealer inventories.

The end-use demand is derived from domestic economic activity and represents actual consumption. The market share section distributes national demand between producing countries based on price and supply availability. Finally, the model accounts for inventory adjustments resulting from differences between expected consumption and actual consumption, and also inventory accumulation for future demand growth.

The first section of this paper will present our approach to end-use demand modeling, drawing on the Softwood Lumber Model to illustrate the methodology. The trade or market share section will then be outlined using the Market Pulp Model of the overall Pulp and Paper Model as an example. Although the customer-dealer inventory sectors of the Forest Products Models are important to the overall functioning of the integrated models, the methodology will not be discussed in this paper.

Modeling End-Use Demand

The DRI Forest Industry Demand Models reflect the modern state-of-the-art for micro-econometric end-use demand modeling. Whereas traditional demand models have largely ignored information contained in market surveys, input-output tables, etc., the DRI Forest Products Models intensively utilize a priori information about the product markets. This information is enhanced by subjecting time series data to the appropriate econometric technique in estimating the set of equations which embody the behavior of market participants.

To embody a priori information about product demand schedules, markets are segmented sectorally and regionally. For instance, the construction market is broken down into:

1. single-family housing starts, multifamily housing starts, mobile homes, and nonresidential building; and
2. four U.S. regions and Canada.

Aggregation of these segments would ignore information which will significantly impact timber demand.

A Comparison of the DRI Forest Products Demand Models to Traditional Demand Models

The FORSIM Demand Model for construction softwood products illustrates the point made above when contrasted with an equation which is typical of the traditional econometric work published in recent years.

TRADITIONAL MODEL (Single Equation):

DEMAND = a + b * HOUSING + c * NONRES + d * PRICE + e * REL. PRICE

where:

DEMAND	=	Softwood Lumber Consumption
HOUSING	=	A Measure of Housing Starts Activity
NONRES	=	A Measure of Nonresidential Construction Activity
PRICE	=	A Lumber Price Index
REL. PRICE	=	A Measure of the Price of Lumber Relative to a Substitute
a, b, c, d, and e	=	Estimated Coefficients

Three major shortcomings of the traditional model are:

It ignores the market research information contained in the usage surveys conducted over the years by the U.S. Forest Service, trade associations, and some private organizations. These surveys have yielded fairly reliable use factors in benchmark years (amount of wood used per home in a benchmark year). It is not difficult, using combined expert opinion, to interpolate and extrapolate from these benchmark data points. Errors found in "blind" statistical estimates of these use factors, in this case the coefficients b and c, are of the order of 100%.

- If one subjects raw time-series data on many variables to statistical analysis, one runs into the problem of multicollinearity: the raw data do not contain sufficient information to sort out the influence of each variable that should be part of the explainers. Wrong signs and non-significance almost always result. In this case, two major end uses of lumber are left out of the equation, presumably because the coefficient estimates on the associated variables (activity measures) were of the wrong sign or were nonsignificant (statistically):

  (a) industrial use of lumber (accounting for about 30% of consumption);

  (b) direct consumer use of lumber in residential repairs, alterations or do-it-yourself jobs (accounting for about 15% of consumption).

- The third shortcoming is that b (the amount of lumber used per home) should be dependent on PRICE but the linear formulation ignores this interaction.

FORSIM MODEL (Multi-Equation):

Equation 1

DEMAND=usef.1 * HOUSING 1 + usef.2 * HOUSING 2&
+ usef.3 * MOBPROD + usef.4 * NONRES + usef.5 * INDPRO
+ usef.6 * R&A + usef.7 * H.HOLDS + NETEXP

where:

DEMAND	=	Softwood Lumber Demand (Consumption plus net Exports)
HOUSING1	=	Single-Family Housing Starts
HOUSING2&	=	Multifamily Housing Starts
MOBPROD	=	Mobile Home Production
NONRES	=	Nonresidential Construction Contract Awards
INDPRO	=	Index of Industrial Production
R&A	=	Expenditures on Residential Repairs and Alterations
H.HOLDS	=	Number of Households
NETEXP	=	Net Exports (Exports minus Imports)
usef.1, etc.	=	Use Factors: Amount of Lumber Consumer Per Unit of End-Use Activity Level

Equation 1 is not a single equation, but represents sets of five equations. There is one set for each of the major solid wood materials (lumber, plywood, etc.); each set contains one equation for each of the four U.S. Census Regions and one for Canada.

Equation 1 is not statistically estimated, but is an "accounting" equation, for which the historical use factors were a priori estimated from the results of market surveys and interpolation.

For prediction purposes however, these use factors have to be forecasted, as well as the end-use activities (housing starts, etc.). Also, demand Equation 1 itself does not have any economic content: it does not indicate what the price elasticity of demand is.

In the FORSIM models, the price elasticity of demand is broken down into two effects; the first is predominantly a substitution effect and the second is primarily an income effect. Separate use factor equations incorporate the substitution effect between wood and non-wood, and the technological change which has enabled builders and other wood users to save on the amount of wood used (tighter construction designs and better lumber grading, for instance):

Equation 2 (Use Factor Equation)

Use Factor = f(TIME, S.REL.PRICE, I.REL.PRICE)

where:

Use Factor	=	Amount of wood used per unit of end-use activity; e.g., board feet of lumber per square foot of floor area in single-family homes.
f	=	Function of
TIME	=	Measure of Time
S.REL.PRICE	=	Price (of wood items for which use factor is modeled) relative to the price of major substitutes (this represents the substitution effect of a change in the wood price).
I.REL.PRICE	=	Price (of wood item for which use factor is modeled) relative to either the overall price level, or relative to the price of the end-product for which wood is used (this represents the "real-price effect" of a change in the wood price).

In the estimation of Equation 2, care must be taken that the coefficients, which are estimated using past data, continue to hold in the future. Here again, traditional econometric attempts have failed. For instance, the price elasticities for softwood lumber demand in home construction published in the literature were estimated on data which covered the 1950s and 1960s. During these two decades, the national average use factor for softwood lumber in new single-family homes in the U.S. declined from 11.3 thousand board feet per unit to 10.3 thousand board feet per unit. However, the decline in usage per square feet of floor area was much greater, from 10.6 board feet per square foot of floor area to 6.2 board feet. This discrepancy was caused by the increase in the average size of new homes: from 1,070 square feet to 1,650 square feet. The low price of lumber had little to do with the increase in the size of homes; the primary cause was the tremendous increase in real income and standard of living of the average U.S. household. Thus, the effect of home size on lumber usage per unit has to be removed from the data, before the statistical estimation of price elasticities over the historical sample period can proceed. We did this by expressing the use factor in a consumption rate per square foot of floor area instead of per housing unit.

In the estimation of the use factor equation, it was impossible to completely separate the effect of price changes from long-run, "autonomous" effect of technological progress. In general, lumber-saving technology is speeded up when the price of lumber rises fast.

However, in the 1950s and 1960s, the real price of construction labor increased fast, not the real price of lumber. The real price of lumber stayed more or less constant from 1950 to 1967; the real price of sheathing plywood came down.

Since sheathing plywood takes less labor to install than board lumber, the real price of installed lumber would have risen faster than that of installed plywood, even if the real plywood price had remained constant. This market advantage encouraged investment in the technology of phenolic glue and structural grade plywood. In the early 1960s, a breakthrough occurred, sheathing plywood production costs started to decline, and its market price followed costs down. Penetration accelerated, so that by the early 1970s almost all structural board lumber had been replaced by plywood.

Thus, if one is interested in estimating the price elasticity of the demand for lumber in the 1950s and 1960s, one would take the ratio of board lumber prices to the sheathing plywood price, as a relative price variable in Equation 1. The coefficient one would estimate would have the right sign (negative) and be statistically significant.

In one way or another, that is what many econometric efforts measuring the price elasticity of demand for lumber have achieved: they estimated the effect of the price of lumber (relative to that of plywood) on the replacement of boards by plywood in the 1960s. However, that substitution was largely complete in 1971, and is irreversible unless relative plywood prices are to rise to unlikely levels. Therefore, price elasticities estimated for the 1950s and 1960s are largely irrelevant for the 1970s, 1980s, etc.

Our estimates of current lumber use factors seem to indicate that lumber and plywood have largely become complementary, rather than competitive construction materials. The most significant development regarding the lumber use factor since 1971 has been prefabrication of building components which saves wood by reducing on-site waste. This trend is continuing into the future. A minor occurrence has been price-induced fluctuations in the substitution of wood inner wall studs (non-load bearing) by steel sheet studs in nonresidential building (and to a limited degree, in residences where the codes permit).

Recently, framing lumber has been gaining ground on brick and concrete in some areas of the country, due to its favorable price relative to these energy-intensive building materials. Our use factor equation reflects these price-induced deviations and slow-downs from the overall downward trend, imposed on the lumber use factor due to ongoing material-saving technological change.

Example: Softwood Lumber End-Use Demand

The demand for softwood lumber is largely derived from the demand for other products. There are three broad end-use markets for lumber:

1. new construction;
2. industrial;
3. repairs, alterations and direct household demand (e.g., do-it-yourself projects).

FORSIM divides these markets further into eight end-use categories, because of two reasons:

(1) wood usage is fundamentally different, or

(2) the cyclical and trend movements in the end-use activities themselves vary.

Table I

End-Use Markets for Softwood Lumber

End-Use Markets	End-Use Categories, Indicators of End-Use Activity
New Construction	
Residential	Single-Family Housing Starts Multifamily Housing Starts Mobile Home Production
Nonresidential	Value of Nonresidential Contracts awarded (1972 dollars)
Industrial	Index of Industrial Production
Repairs & Alterations	Consumer Expenditures on Residential Repairs & Alterations (1972 dollars)
Other	Direct Household Use Net Exports

FORSIM has distinguished five regional markets for each end use (except exports, of course):

1. U.S. Northeast Census Region
2. U.S. North Central Census Region
3. U.S. Western Census Region
4. U.S. Southern Census Region
5. Canada

The FORSIM Model contains 26 separate use factors for softwood lumber:

- 5 for usage in single-family homes (in 4 U.S. regions and Canada);
- 5 for usage in multifamily homes (in 4 U.S. regions and Canada);
- 1 for usage in two-family homes (in Canada);
- 1 for usage in row houses (in Canada)
- 4 for usage in mobile homes (4 U.S. regions)
- 5 for usage in nonresidential construction (4 U.S. regions and Canada);
- 2 for usage in industrial production (1 U.S., 1 Canada);
- 1 for usage in repairs and alterations (U.S.);
- 2 for direct, "odd-job," usage by households (do-it-yourself shoulder trade in U.S. and Canada)

NOTES:

(1) Wood use for Canadian mobile homes and repairs and alterations is included in an "other" category for which total consumption is estimated directly.

(2) End use of wood by industry and for repairs and alterations is broken down by regions after a national total is estimated.

Consumption in each of the residential construction categories (single-family, multifamily and mobile home construction) are all modeled in the same manner. The basic formulation for each end-use category is as follows:

$$\text{Residential Construction Demand} = \text{No. of Housing Starts or Mobile Homes Produced} * \text{Av. Home Unit Size} * \text{Use Factor}$$

For each of the other end-use demand categories, similar formulations are used. Thus, lumber demand for other than residential construction is calculated as follows:

Repairs & Alterations Demand = Expenditures on Repairs & Alterations * Use Factor

Nonresidential Construction Demand = Value of Nonresidential Contracts Awarded (F. W. Dodge) * Use Factor

Industrial Demand = Industrial Production Index * Use Factor

Direct Household Demand = Number of Households * Use Factor

Total lumber demand is simply an aggregate of these seven end-use categories plus net exports.

Housing starts, mobile home production, home sizes, expenditures on repairs and alterations, value of nonresidential contracts awarded, industrial production index, and the number of households are not forecast by the FORSIM Model. Projections for these variables are taken as exogenous inputs from other sources. These activities are assumed not to be influenced significantly by changes in lumber prices since primary lumber prices represent only a fraction of their unit costs. Use factors are a key endogenous element in the FORSIM Model and are discussed in the following section.

As noted above, for the two end-use markets where regional use factors have not been developed, FORSIM uses regional demand ratios to determine regional consumption. These two end uses are the industrial, and the repairs and alterations markets. Regional consumption in these cases is derived as follows:

REGIONAL DEMAND = NATIONAL DEMAND * REGIONAL DEMAND RATIO

Functional Form of Use Factor Equations

Autonomous technological change can be thought of as an ongoing process which was set in motion by a long-past price shock or price pressure, or by a breakthrough in a related field. An example of the latter was the perfection of the fabrication of exterior phenolic glue (in the 1950s and early 1960s) for structural grade plywood (which then dropped rapidly in price, and replaced lumber sheathing).

Thus, if the relative price of lumber remains fixed, the use factor for lumber changes over time as a function of autonomous technological change (as do the use factors for all construction materials).

The use factor equation may be written in general form as:

(1) $U = f(T,P)$

where:

U	=	Use Factor
f	=	Function of
T	=	A Time Measure of Technological Change
P	=	Price

Most autonomous processes go through three staged "learning curves," which look like slanted s-shaped graphs. The upper part of such an s-curve can be approximated by a logarithmic function:

(2) $U = a+b * \log(T), g(P)$

where:

a,b	=	Coefficients
log	=	Natural Logarithm
g	=	Function of

Demand functions of derived producer demand should have price effects parallel to those of final consumer demand. Instead of maximizing utility, the value of the end product is maximized. Thus one should be able to separate the price effect on quantity demanded into an income effect and a substitution effect:

(3) $U = a+b * \log(T), g1(P), g2(P)$

where:

g1	=	Function of (Substitution Effect of Price)
g2	=	Function of (Income Effect of Price)

Substitution Effect

Let gl(P) be the substitution effect. Then P, the price measure, should be expressed as the price of lumber relative to the price of available substitutes:

(4) U = a+b * log(T), gl(LUINDEX/WPIC), g2(P)

where:

LUINDEX = A Price Average for Lumber Products
WPIC = A Price Average for Competing Products

The specification of gl, the functional form in which the substitution effect enters the equation, is derived as follows:

Let us ignore the income effect for a while.

Let us rewrite equation 2 again as:

(5) U = a+b * log(T), gl(P).

The substitution effect should speed up technological change if lumber prices rise relative to lumber's substitutes (potential and available ones), and slow it down when lumber prices fall relative to lumber's substitutes:

(6) b = g3(LUINDEX/WPIC)

where:

b = The Original Coefficient on the Logarithm of Time (e.g., al)
g3 = Function of (Substitution Effect of Prices)

We can postulate the functional form of g3 to be as follows:

(7) $b = c+d_1 * \log(LUINDEX/WPIC)$

where:

c, d_1 = Coefficients

Substituting (7) into (5), we have:

(8) $U = a+c * \log(T) + d_1 * \log(T) * [\log(LUINDEX/WPIC)]$

From (8) we see that after price shock (i.e., if LUINDEX/WPIC explodes up or down), new technological change will be initiated, as U will follow a distinct different path. One could make this new path autonomous and the substitution permanent (like the plywood-boards substitution of the 1960s). This can be accomplished by shifting c * log(T) (increase or decrease c), after the price shock passes and LUINDEX/WPIC returns to the previous value. Otherwise, the substitution is reversible.

Not all substitution involves technological change. The reversible part of the elasticity of U with respect to the relative price of lumber (LUINDEX/WPIC) should be written as:

(9) e = @log U/@ log Pr

where:

e = Elasticity
@ = First Derivative
Pr = LUINDEX/WPIC

However, this elasticity is not constant. As more products are developed (e.g., plastics, reconstituted wood, etc.), this elasticity increases. Since U is in a secularly declining trend, due to autonomous technological change, we could postulate that the rate of increase in that elasticity is declining over time:

(10) e(t) = d2 * log(T)

Substituting (10) into (8) we get:

(11) U = a+c * log(T) + d * log(T) *[log(LUINDEX/WPIC)]

where:

d = d1 + d2

The Income Effect

Let g2(P) be the income effect. Then P, the price measure, should be expressed as the price of lumber relative to the price of the end product for which lumber is used. When the price of lumber rises relative to the price of the end product, less lumber is used in constructing that product (and vice versa).

In the case of the use factor for single-family homes in the South, for instance, the price of the end product is the average price of new single-family homes sold in the South. Since this use factor is expressed in terms of wood usage per square foot, the home price is also expressed as price per square foot. Thus in this case, we can write:

(12) g2(P) = r * log(LUINDEX/(PAHUINSOLDNS@SO/ONESIZESO))

where:

PAHUINSOLDNS@SO = The average price of new single-family homes in the South.
ONESIZESO = The average size of new single-family homes in the South.

By combining (11) and (12) we arrive at the expanded functional form of Equation 3.

Estimation of Use Factor Equations

For model management purposes (and because of lack of reliable annual data on each use factor separately) the following scheme was adopted:

1. Estimate as a "master" use factor equation, the equation for the most important lumber usage. The master equation was estimated using the specification derived from combining equation (11) and (12).

2. Estimate the other use factors as simplified functions of the master equation.

As the master for softwood lumber, the use factor for southern single-family housing starts was chosen. Southern single-family starts in 1978 took 14.6% of all softwood lumber consumed in the U.S., well ahead of 9.2% for single starts in the West, or 8.8% for industrial use in the North Central region.

The equation for this use factor was estimated using quarterly data from 1950:1 to 1979:1. For the fifties and sixties a special "learning curve" term containing the price of sheathing plywood relative to the price of board lumber was added to reflect the replacement of boards by sheathing plywood. This term was deleted starting in 1971:1, with the completion of that replacement.

The result reported below is thus for the quarters 1971:1 through 1979:1. The resulting equation was used to simulate demand in the complete FORSIM Model through 1990, to check it for long-run consistency.

(13) $$\log(LUHCOSO) = \underset{(.152)}{2.508} - \underset{(.0309)}{0.1304} * \log(TIME)$$

$$+ \sum_{k=0}^{12} W_k * \left[\log(TIME_k) * \log(LUINDEX_k/WPIC_k)\right]$$

$$+ \sum_{j=0}^{1} W_j * \left[\log(LUINDEX_j/(PAHUINSOLDNS@SO_j/ONESIZESO_j))\right]$$

$$\sum W_k = \underset{(.00491)}{-0.03106} \qquad \sum W_j = \underset{(.0205)}{-0.1085}$$

$\bar{R}^2 = 0.95$
SEE = 0.008 (normalized)
OLS 1971:1 to 1979:1

where:

log	=	Natural Logarithm
LUHCOSO	=	Softwood Lumber Use Factor, Southern Single-Family Starts, Board Feet Per Square Feet of Floor Area
LUINDEX	=	Weighted Average of Softwood Lumber Prices
WPIC	=	Weighted Average of Competitive Construction Materials
PAHUINSOLDNS@SO	=	Average Price, New Single-Family Homes Sold in South
ONESIZESO	=	Average Size, New Single-Family Homes Started in the South

The remaining use factors were constructed using a linear model of the form Y = a+b*X. In all cases, the X variable is the "master" use factor, while Y represents the use factors for other end uses (and regions).

Modeling Regional and International Trade

The end-use demand sectors of the DRI Forest Products models are only portions of fully structured and integrated models. Some of the other major sectors are: inventories (both consumer and producer), regional and international trade, production costs, capacity expansion, and prices. We are exploring the demand sectors of our Forest Products models in this paper. End-use demand is only one of the sectors associated with the total demand portion of the models. Consumer inventories and regional trade are the other sectors which contribute to the demand portion of the models. We would like to focus on the work that we have done in modeling trade for the remainder of this paper.

Presently, the major DRI Forest Products models which have fully developed international trade sectors are market pulp and newsprint, while the solid wood products model (FORSIM) incorporates a North American regional trade sector. The comments in this section of our paper will be confined to the international trade sector of the market pulp model as an example of the methodology used in the other models. Some comments will also be made on the regional aspects of the FORSIM North American model.

The market pulp model is, as is the case for the other Forest Products models, a fully structured representation of the market pulp market. We stress this fact because the operation of the trade sector is completely dependent on the integrated nature of the model. The market pulp model is dependent on our world pulp and paper model for inputs. The world pulp and paper model looks at worldwide total paper and board demand by 13 regions and total wood pulp demand by the same number of regions. Total wood pulp demand is broken down by three major grade groupings: mechanical and semichemical, bleached kraft, and other chemical paper grade pulp. Net import demand for the three pulp groupings is estimated for only the world regions exclusive of the Norscan countries and Brazil (Norbrascan). Net import demand is a function of total regional pulp demand, domestic capacity, and domestic production costs relative to the import price of pulp. Net import demand for each of the pulp grades is summed across the non-Norbrascan regions to arrive at the overseas export market for Norbrascan producers.

The market pulp model concentrates on chemical paper grade market pulp in the Norbrascan countries. The grades covered are bleached softwood kraft, bleached hardwood kraft, and other chemical paper grade pulp. The market pulp model takes as inputs from the world pulp and paper model the overseas export market and total (integrated plus market) pulp demand in the Norbrascan countries for each of the pulp grades. The overseas demand for Norbrascan bleached kraft pulp, which comes directly from the world pulp and paper model, is split into softwood and hardwood by projecting availability of each of the grades. The primary outputs of the market pulp model are domestic market pulp shipments, exports, producer inventories, production, capacity, and production costs for each of the Norbrascan countries. Seven selected pulp prices are also estimated within the model. An overview of the full structure of the market pulp model is included at the end of the paper.

The trade sector of the market pulp model is concerned with the estimation of the shares for each of the Norbrascan countries in the overseas export market for the various pulp grades. The export shares are estimated as:

(14) $$\text{EXSH } i = f\left(\text{CAPEX } i \Big/ \sum_{i=1}^{6} \text{CAPEX } i\text{ , AVCOST } i\ /\text{AVCOST}_{NBR}\right)$$

where,

EXSH i	=	Export share of country i
CAPEX i	=	Capacity available for overseas export of country i
$\sum_{i=1}^{6}$ CAPEX i	=	Sum of capacity available for overseas export in Norbrascan
AVCOST i	=	Average delivered variable production cost per ton of country i in U.S. dollars
AVCOST_{NBR}	=	Weighted average delivered variable production costs per ton for Norbrascan in U.S. dollars

The first independent variable, relative capacity available for export, is included to take account of the changes in potential supply from each of the competing regions. Capacity available for export is defined as:

(15) $$\text{CAPEX } i = \text{CAP } i - \text{SDQ } i + \text{IPM } i$$

where,

CAP i	=	Market pulp capacity in country i
SDQ i	=	Domestic market pulp shipments in country i
IPM i	=	Producer inventories of market pulp in country i

As can be seen, the definition of capacity available for export incorporates the explicit assumption that domestic demand will be filled before overseas demand. The capacity available for export in Canada is defined somewhat differently by subtracting shipments to the United States along with domestic shipments. The assumption is that Canadian producers will supply U.S. demand before looking overseas. Producer inventories are included because inventories should be thought of as potential supply, which is really the definition of capacity.

The relative capacity for export term has a positive sign associated with it. That is, as a country's share of total potential overseas supply of market pulp rises, then its share of the overseas export market will expand. The importance of a fully integrated model shows up in this specification of the trade sector. The dependence on market pulp capacities in the export share determination requires an endogenous capacity expansion sector to allow reasonable simulation and long range forecasting capabilities.

The other independent variable in the export share equation is relative production costs. This variable is actually a proxy for relative transaction prices charged by the various supplying region on the overseas export market. We use average variable production costs as proxies for average transactions prices for two main reasons:

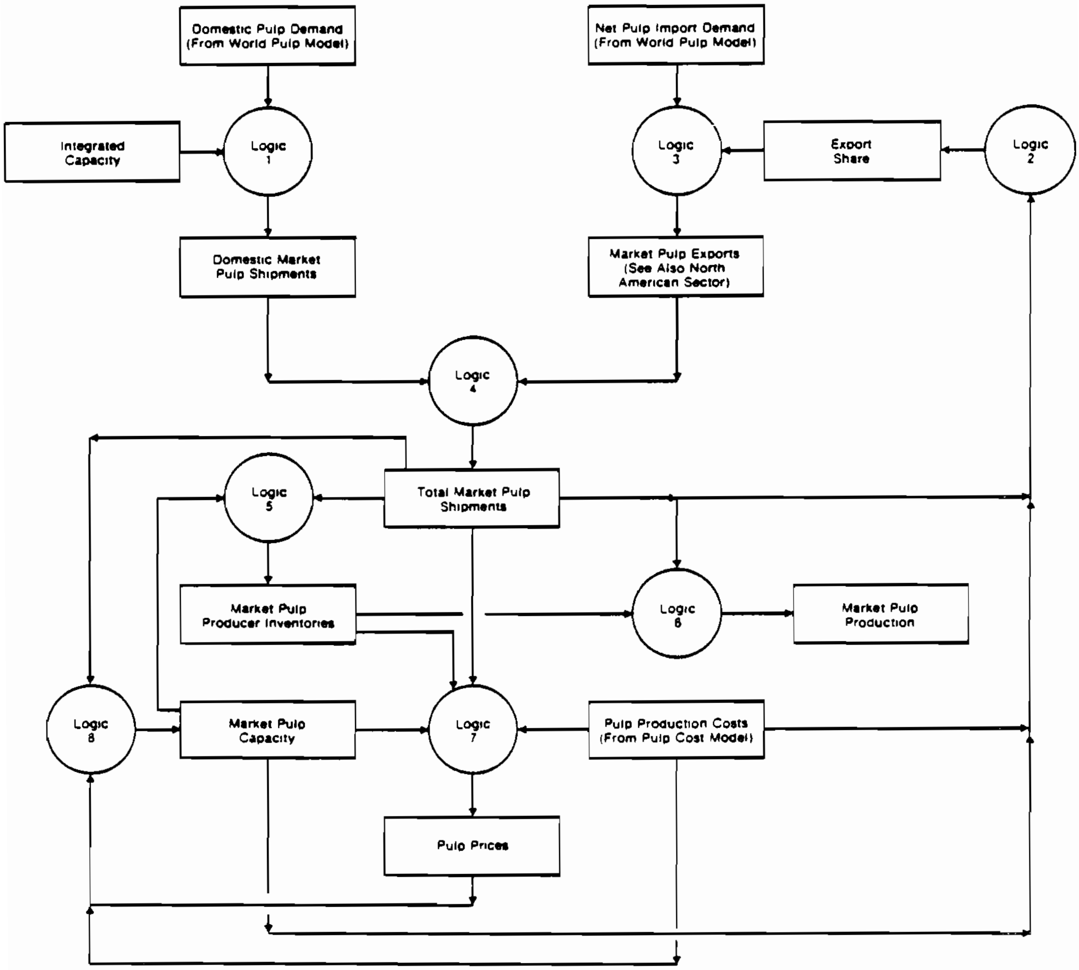
- Spot prices are very hard to determine historically and are needed to develop an average transaction price.
- Prices are based very heavily on average variable production costs, making variable production costs a good indicator of price behavior especially in weak market conditions.

We have been able to gain explanatory power through the use of relative production costs, particularly in explaining the loss of Scandinavian share in the second half of the 1970s and the corresponding North American share gain. The use of variable production costs in the share determination requires a model which integrates an international cost sector. The market pulp model includes a production cost sector which incorporates estimates of eight cost components for Sweden, Finland, U.S. South, U.S. Pacific Northwest, B.C. Coast, B.C. Interior, eastern Canada, and Brazil.

The impact of each independent variables is estimated using a polynomial distributed lag structure. Time lags are built into the export share determination to more closely represent the lags inherent in the changing behavior in the real economic world. Each of the DRI Forest Products models relies heavily on the incorporation of time lags in the model structure, especially since almost all the models are quarterly in frequency.

In conclusion, the international trade sector of the market pulp model does not rely on a complicated specification. In fact, the sector should probably be noted for its relative simplicity. However, the sector does rely heavily on being only a portion of a fully integrated model of both the demand and supply sides of an international market, which gives the opportunity to expose and explore the interrelationships of the various elements within the market.

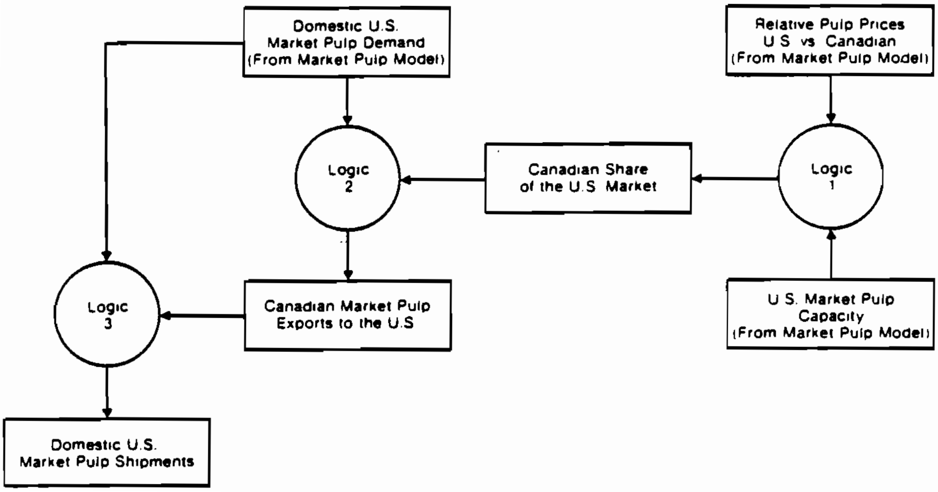
Market Pulp Model



Countries Included:
- United States
- Canada
- Sweden
- Finland
- Norway
- Brazil

Pulp Grades Included:
- Bleached Softwood Kraft
- Bleached Hardwood Kraft
- Other Chemical Paper Grade

North American Market Pulp Sector



Market Pulp Model

The market pulp model is an extension of the world pulp and paper models. Total import demand for bleached softwood kraft, bleached hardwood kraft, and other chemical paper grade pulp from world regions other than Norscan and Brazil feeds in from the world pulp model. Total domestic demand for bleached softwood kraft, bleached hardwood kraft, and other chemical paper grade pulp for each of the Norscan countries and Brazil is also taken from the world pulp model (see World Pulp and Paper Model Documentation). Production costs for bleached softwood and hardwood kraft, by Norscan region and cost component, feed into the market pulp model from the pulp cost submodel (see Pulp Cost Model Documentation).

The market pulp model concentrates on the Norscan countries (United States, Canada, Sweden, Finland, and Norway) and Brazil. The pulp grades covered in the model are bleached softwood kraft, bleached hardwood kraft, and other chemical paper grade. Major outputs of the model are:

- Domestic market pulp shipments
- Market pulp exports (and affiliated exports from Canada to the United States)
- Total market pulp shipments
- Producer inventories of market pulp
- Market pulp production
- Market pulp capacity
- Pulp prices delivered to Northern Europe and the United States

The outputs listed above are generated for each of the Norscan countries and Brazil, and for each of the pulp grades. The exception is for pulp prices, where only bleached softwood and hardwood kraft prices are analyzed.

Description of Model Methodology

This section will describe in detail the operation of the market pulp model. The model will be broken down into its major components and the operation of these components will be described. A graphic display of the model and its components is presented by the flowchart of the market pulp model which precedes this section. Numbers in parentheses are associated with the logic blocks on the flowchart.

(1) Domestic Market Pulp Shipments--Domestic market pulp shipments in Norscan and Brazil are estimated by a two-step process. First, the share of market pulp shipments versus total apparent consumption is estimated as a function of total apparent consumption relative to integrated capacity. This share is then multiplied by total apparent consumption to arrive at the market pulp shipments forecast. Total apparent consumption is obtained from the world pulp model, while integrated pulp capacity is estimated exogenously.

This methodology is used for each Norbrascan country except the United States and each pulp grade other than bleached softwood kraft in Brazil. A significant portion of the market pulp demand in the U.S. and the bleached softwood kraft demand in Brazil is filled by imports. Therefore, the assumption that domestic market pulp demand is equal to domestic market pulp shipments, which is implicit in the above methodology, does not hold for the U.S. and Brazil. The estimation procedure for these areas is to first forecast the share of market pulp demand relative to total apparent consumption, where market pulp demand is equal to domestic market pulp shipments plus imports of market pulp. This share is again a function of total apparent consumption relative to integrated capacity.

Market pulp demand is calculated by multiplying this share by total apparent consumption. The share of imports in the total demand for market pulp is estimated as a function of market pulp demand relative to domestic market pulp capacity and the price of imported pulp relative to the price of domestic pulp. Imports of market pulp are equal to the import share multiplied by total market pulp demand. Domestic market pulp shipments are total market pulp demand minus market pulp imports.

A further step is required to complete the trade balance between Canada and the U.S. Affiliated shipments of pulp from Canada to the U.S. must also be forecast. The share of affiliated exports from Canada relative to total apparent consumption is a function of total apparent consumption relative to integrated capacity. Affiliated exports are equal to this share multiplied by total apparent consumption.

(2) & (3) Market Pulp Exports—The estimation of market pulp exports is also a two-step process, where an export share is first estimated and then exports are calculated by multiplying this share by total pulp net import demand by non-Norbrascan regions. The export share is estimated as a function of relative capacity available for export and relative variable production costs. Capacity available for export is defined as market pulp capacity less domestic market pulp shipments. Relative capacity available for export is defined as export capacity in one country relative to total Norbrascan export capacity. Market pulp capacity is endogenous to the market pulp model, with the description of the estimation procedure found at (8) below. Domestic market pulp shipments come from (1) above.

Relative average variable production costs are defined as the average variable production costs in one country relative to average Norbrascan variable production costs. Average Norbrascan variable production costs are defined as the weighted average of the production costs for each Norbrascan region, with the weights being the share of market pulp shipments from each region compared to total Norbrascan shipments. Average variable production costs are taken from the pulp cost submodel. See the documentation of the pulp cost submodel for details of the component costs included in average variable costs.

Canadian market pulp exports are the summation of exports to the U.S. and exports to the rest of the world. The estimation of exports to the U.S. is detailed in (1) above, while exports to the rest of the world are determined in this section. Total Canadian pulp exports are market pulp exports plus affiliated exports to the U.S. taken from (1) above.

(4) Total Market Pulp Shipments—Total market pulp shipments are domestic market pulp shipments from (1) plus market pulp exports from (3).

(5) Producer Inventories of Market Pulp—Producer inventories are estimated in a two-step process. Production relative to shipments is a function of lagged producer inventories relative to shipments and market pulp capacity relative to shipments. Producer inventories are equal to producer inventories from the previous quarter plus producer inventory change (which is calculated by multiplying production relative to shipments by shipments, and then subtracting shipments). Market pulp shipments come from (4) above, lagged producer inventories from this step, and market pulp capacity from (8) below.

(6) Market Pulp Production—Production is shipments from (4) plus producer inventory change from (5).

(7) Pulp Prices—Two estimation procedures are used for pulp prices. The first is for our "marker" pulp price, which is Scandinavian bleached softwood kraft pulp (delivered Northern Europe). This marker price is estimated as a loglinear function of average variable Norscan bleached softwood kraft production costs and a nonlinear function of total Norscan producer inventories relative to total Norscan shipments and total Norscan shipments relative to total Norscan market pulp capacity. The loglinear function with respect to costs implies a percentage relationship between cost and price. Only variable production costs are present in the price equation; the impact of capital costs is taken account of in the capacity term.

The other pulp prices are estimated relative to the marker pulp price. This relationship is a function of average variable production costs in the region and grade with which the pulp price is associated relative to average Norscan bleached softwood kraft production costs and total Norscan shipments relative to total Norscan market pulp capacity. The price is equal to this relative term multiplied by the marker price.

(8) Market Pulp Capacity—Market pulp capacity is forecast in two steps. The first is to estimate the tonnage change in capacity. Capacity is then equal to capacity in the previous quarter plus change in capacity. Capacity change is a function of real unit profit margin and change in demand. Both of these terms have very long time lags attached, with 2-4 years common. Unit profit margin is calculated as the price per ton of pulp minus the total per-ton production cost for a new mill divided by unit capital cost. Unit capital cost is calculated as the total capital cost of a new mill divided by the tons produced per year at the mill. Real unit profit margin is the unit profit margin minus an alternative rate of return, which is represented by a long-run interest rate such as the yield on corporate bonds or on a long-term government bond. Change in demand is the quarterly change in total market pulp shipments. (See the section in this methodology documentation on investment modeling for a more detailed discussion of capacity expansion estimation procedures.)

APPROACHES TO THE ANALYSIS OF PAPER DEMAND AND SUPPLY IN WESTERN EUROPE

Esko Uutela[1)]

Abstract: This paper gives an overview of methods and techniques used in analysing and forecasting paper demand and supply in Western Europe. Special characteristics of the Western European markets are described. Developments, major draw-backs and advantages of different approaches are reviewed. The contribution of subjective assessments to the whole forecasting process and the importance of data banks and data quality are also discussed.

Additional keywords: Demand and supply analyses, market characteristics, time-series analysis, cross-section analysis, quantitative and qualitative forecasting, paper and board.

INTRODUCTION

In 1980 Western Europe consumed 41.5 million tons of paper and paperboard, accounting for 24 per cent of the total world consumption. After North America, Western Europe is the second largest paper market in the world. And in the international paper trade Western Europe's role is even more important: about half of the world paper trade (34 million tons in 1980) takes place in the Western European markets. Against this background, it is natural that the future development of paper demand and supply in Western Europe has always aroused great interest among paper and board exporters.

Allowing for variations due to business cycles, the Western European demand for paper and board grew quite steadily until the early 1970s, with a compound growth of 5.1 per cent a year between 1965 and 1973. But historical demand trends were badly disturbed in the 1970s by exceptional changes in the industry's techno-economic environment. The first oil crisis accompanied by a world economic recession and price movements can be blamed for most of these disturbances, but many other factors, like declining paper grammages and changing packaging practices, have also affected demand trends.

The paper demand forecasts prepared by most forecasting institutes or companies prior to and during the first oil crisis have proved to be out of scale because of their strict reliance on historical development. Past trends can no longer be simply extrapolated to the future, so more sophisticated forecasting methods must be developed.

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In the following different approaches and their usefulness in forecasting paper demand and supply are briefly discussed. Although the emphasis is mostly on long-term models, some short-term aspects are also commented on.

CHARACTERISTICS OF WESTERN EUROPEAN MARKETS

A number of special characteristics should be kept in mind when analysing paper demand and supply in Western Europe. These market characteristics may cause crucial differences compared with forecasts of the US market.

First, although Western Europe can be examined geographically as an entity, it is composed of 19 major countries that all have their own economic, cultural and social background affecting consumer preferences and the use of paper and board. As in many other products, the general attitude towards consumption is much more conservative in Western Europe than in North America.

Second, the income distribution in Western Europe varies from country to country; in some countries the equalization of income is well advanced, in others income is still quite unevenly distributed. Furthermore, there has not been as broad a middle class with strong purchasing power in Western Europe as in the USA.

Third, population grows very moderately, or even declines in many Western European countries, so the growth of consumption is mostly due to an increase in per capita consumption.

Fourth, international trade in paper and board is much more important to the Western European countries than to the USA. There are big net importers such as the UK, the Fed. Rep. of Germany and France, whereas exports are of vital importance to the Nordic countries and Austria.

Fifth, the structure of industry and its operating conditions are rather different in Central and Southern Europe compared with those in North America and the Nordic countires. In addition state involvement in the industry and foreign trade through subsidies and/or restrictions complicates the supply analysis in many countries.

Finally, the poor reliability and availability of statistical data in certain Western European countries set limitations to a detailed analysis of the whole region. Confusion may occur also because of different definitions of terms used.

ALTERNATIVE FORECASTING APPROACHES

Several criteria for classifying alternative forecasting or projection methods have been discussed in the literature. Even the meaning of the term "forecast" has been discussed and differentiated from the related words "projection" and "estimate" by some authors (Hair and Josephson 1970, Holland 1970). One of the most suitable definitions may have been given in a paper by Gregory and others (1971, p. 3): "forecast will be defined as a quantitative estimate of some specified future condition or event, made as a result of rational study and available pertinent data".

One of the main questions of forecasting is whether demand and supply should be determined simultaneously according to the Marshallian theory, or whether they can be treated separately in a sequential analysis. This problem has been considered in many studies (Hair 1967, Gregory 1966, Åberg 1968).

In Western Europe forecasting studies have mostly concentrated on demand or consumption only (FAO 1963, Åberg 1968, Sundelin 1970), although there are studies that also deal with supply forecasts (FAO/ECE 1976, FAO 1977a) but not simultaneously.

The following three criteria are commonly used in classifying different methods: the forecasting technique applied (e.g. Spencer and others 1961), the scale of measurements (quantitative/qualitative techniques; Wheelwright and Makridakis 1977) and the type of model (Hair 1967).

By combining these three criteria, the following approaches to the Western European analysis were selected for further discussion:

1) the traditional time-series approach
2) the cross-sectional and combined cross-sectional and time-series approach
3) the single-equation regression approach
4) simultaneous equation models
5) subjective panel and market research approaches

Time-series Approach

A classical approach to forecasting is to base the analysis on historical observations of the endogenous variable only. A pattern is searched by using smoothing or adaptive filtering techniques, decomposition methods or some more complex techniques like the Box-Jenkins method. The use of these methods is discussed in detail by Wheelwright and Makridakis (1977) and Jenkins (1979).

Time-series models have been widely used in earlier work on demand analysis in Western Europe. They still have supporters among researchers who, after trying more sophisticated mathematical and statistical methods, have concluded that "simplest is best" (ECC Int'l 1978). However, the dangers of projecting historical time series of demand have been evident during times when historical trends have been disturbed. The dangers involved in simple time-series models have been discussed in earlier studies (FAO 1969, FAO 1963, Sundelin 1976). Because of these problems, many institutes and companies preparing paper demand forecasts have started to use other methods.

Cross-sectional Approach

The pure cross-sectional approach, in which observations of variables relate to different countries at a certain point of time, also has its drawbacks. Although it increases the variability of observations compared with time-series data, it is questionable whether these variations across countries are relevant in explaining changes over time (Buongiorno 1979).

A combination of cross-sectional and time-series analysis has long been used in forecasting paper demand. Traditionally, cross-sectional paper demand models have been simply based on the observed correlation between per capita income (GDP or GNP) and per capita consumption of paper and board. To avoid the static nature of cross-sectional models, efforts have been made to include changes in cross sectional curves over time by introducing a "time trend factor" in the model (FAO 1960, FAO 1963) or by separating the effects of income and other factors on a country's consumption (Sundelin 1970). Sundelin (1977) has further divided other factors into "a general trend" and "a specific country trend".

Another way to allow for technological and other changes over time has been presented by Buongiorno (1977). In this model with cross-sectional data, current paper consumption was explained by current GDP, lagged paper consumption (t-10) and lagged GDP (t-10). The results showed a good statistical fit for paper and board in the light of historical data, especially for a group of 24 developed countries.

Price effects on paper demand have been excluded from most paper demand studies. Normally, unchanged relative prices have been assumed. Åberg (1968) concluded that the demand for paper and board in Western Europe has very low price elasticity. This was justified, because real prices did not increase much before the first oil crisis. But studies made after the mid-1970s (FAO 1977a, Buongiorno 1978) have shown a clear negative price elasticity of paper demand.

However, in applying the cross-sectional approach to Western Europe, there are some problems which cannot be disregarded. The number of observations (= countries) at higher income levels is small and the variation interval of GDP is relatively small for the needs of long-term forecasts. There is too little indication of the experience from other countries. For reasons discussed earlier in this paper, it is not self-evident that the Western European countries will follow the US pattern of consumption. The number of observations and the variability of data can certainly be increased by using pooled time-series and cross-sectional data, as in two recent studies (Buongiorno 1979, Buongiorno and Gilles 1980). However, even then it should be remembered that the number of countries, whose analogous development the model utilizes, has not been changed.

Another problem is the poor comparability of GDP in different countries at different points of time. The choice of deflator, base year and currencies affect rankings between countries. The current world monetary system with strongly fluctuating exchange rates has made reliable comparisons between countries extremely difficult.

Single Equation Regression Approach

In this context the single equation regression approach refers to an analysis carried out in a single country for a single dependent variable. This type of analysis is frequently used for analysing the demand for a specific grade of paper and board. It is based on the identification of end-use indicators associated with the actual consumption. The number of independent variables can vary, but normally it is quite small, i.e. less than five.

The relationship between the dependent variable (demand) and independent variables is functional but not necessarily causal. The most commonly used independent variables include population, gross national product or gross domestic product, population, industrial production, private consumption and the number of households. This approach has been discussed in more detail for example by Hair (1967).

In the paper industry sector of Western Europe, single equation econometric models have been developed mostly for a single paper or board grade and national markets (Riihinen 1962, Simula 1971). Their use in practical forecasting situations is limited by the large number of explanatory variables whose forecast values should be determined in advance.

Simultaneous Equation Models

Simultaneous equation models are usually constructed for one country at a time. Most of the studies published concern the US market (e.g. McKillop 1967, Adams and Haynes 1980), although some also deal with the foreign trade in forest products (McKillop 1973).

Some attempts have been made to develop a market model for the whole of Western Europe with links to North America (Baudin 1980). However, multi-equation models have not been widely used in analysing and forecasting paper demand and supply in Western Europe. The lack of pertinent data and problems in the selection of variables have been the main reasons for their limited use.

Techniques Including Subjective Assessment

Subjective techniques discussed in this paper are the use of expert panels and market research for analysing supply.

Review panels of paper industry experts have been used to assess the proposed outlook for consumption (FAO 1977b). To this end a preliminary proposal is prepared in advance using common quantitative techniques. The final consumption forecasts are obtained by combining the original proposal and the judgment of the experts.

This approach, though on a reduced scale, has been used in a recent study by JAAKKO PÖYRY (1981) to estimate the future effects on the demand for paper and board of substitution by electronic information systems, advances in packaging and declining grammages of paper. The value of the information gathered through review panels lies in the fact that it contains a priori insights of experts. The use of expert panels improves the possibilities for evaluating future turning points and new influences on demand.

An important question is at which stage of analysis expert opinions should be taken into account. In the JAAKKO PÖYRY (1981) study, this was done at several stages of the forecasting process, starting from the data analysis and ending with the evaluation of the results.

The Market Research Approach to Supply Analysis requires a good data gathering and retrieval system. Forecasts of future paper capacity require data on future new projects, expansions, rebuilds and shut-downs. FAO capacity surveys (e.g. 1981) provide some rough information on future capacity development. Unfortunately, this information is often not sufficiently accurate and up-to-date, e.g. for an investment decision.

According to experience gained at JAAKKO PÖYRY, a more accurate analysis of supply can be based on information compiled machine by machine into a worldwide paper machine data bank. When making supply forecast, all components of capacity change (new projects, expansions and rebuilds, shut-downs and grade changes) must be analysed in detail. The problem is that complete information especially on shut-downs, grade changes and minor rebuilds of paper machines cannot be obtained in advance. Part of future shut-downs can be subjectively assessed based on data on the age and size structure of machines and the competitiveness of the industry. Normally, this type of analysis is restricted to a 5-years period at the most.

CONCLUSION

Several models and approaches have been applied in analysing paper demand and supply in Western Europe.

Good results have been achieved both with complicated and relatively simple methods. However, it is evident that more sophisticated approaches will gain more ground in future. A good model for Western Europe should at least:

1) rely on a sound theory
2) utilize all available data on factors relating to dependent variables
3) allow for variances among countries
4) not cost more than the value of additional information

The emphasis has so far been on consumption analysis by quantitative techniques. Supply and international trade components have been less studied. Growing requirements on the quality and availability of data will increase the importance of systematic data collection and continuous updating of data banks. Much research work is needed before a comprehensive market model for Western Europe is available.

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ANALYSIS OF PULP AND PAPER SUPPLY AND DEMAND IN WESTERN EUROPE - DISCUSSION

William McKillop [1]

Abstract - This discussion outlines the key variables needed to estimate pulp and paper demand and supply relationships for individual countries. Because of the importance of international trade a comprehensive multi-country approach is needed for modeling the Western European pulp and paper sector.

Esko Uutela has done an excellent job of describing the major characteristics of Western European markets for pulp, paper and paperboard. Equally useful is his categorization of various past studies, such as those by Aberg (1968), Sundelin (1970) and Buongiorno (1978).

It has been argued that comprehensive econometric modeling using annual data is the most appropriate approach to forecasting pulp, paper and paperboard demand and supply for individual countries. This approach requires careful specification of economic models of supply and demand which recognize all major influences in a theoretically rigorous way. A description of such models of pulp and paper demand and supply are given in McKillop (1971). Major variables identified on the supply side were (a) prices of inputs such as labor, chemicals, power and raw materials, (b) production capacities and operating ratios, (c) technological change, and (d) factors relating to international trade such as rates of exchange, freight rates and tariff levels. Major demand variables were (a) population, (b) income and income distribution, (c) index of general industrial activity, (d) measures of competitiveness of substitutes, and (e) technological change, especially in packaging and in the communications media.

In the case of Western European countries, specification and estimation of relevant supply and demand relationships should be relatively straightforward except for two aspects. On the demand side, developing and forecasting suitable measures of technological change in packaging and in communications may involve considerable thought and preliminary investigation. On the supply side, the picture is complicated by the prominence of international trade referred to by Mr. Uutela, with the United Kingdom, the Federal Republic of Germany and France being large net importers, and the Nordic countries and Austria being major net exporters. Furthermore, imports from North America must also be considered.

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The importance of this trade makes it clear that individual countries cannot be treated in isolation when modeling the pulp and paper sectors in Western Europe. There are several possible approaches to developing a multi-country pulp and paper model. The most comprehensive, but also the most time-consuming and expensive approach, is to model demand and supply relationships between each pair of trading partners. A less comprehensive approach would be to model only net imports or net exports, and then link these relationships to national models. A third approach (and perhaps the best compromise between completeness and computational cost) would be to treat each major producing country as a supply region and each major consuming country as a demand region. A set of supply and demand relationships could then be estimated and equilibrium levels of price and trade flows found by iterative or optimizing techniques.

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ALTERNATIVE APPROACHES FOR ESTIMATING PRODUCTION TECHNOLOGY IN FOREST PRODUCTS INDUSTRIES

Fatma Sherif [1/]

Abstract: This paper reviews recent developments in the production theory. It describes two recent approaches in estimating production technology in an industry that can be implemented in the forest products industries. They place no *a priori* restrictions on the elasticities of substitution, returns to scale and technological changes. Using recently developed flexible functional forms, they allow for the generalization of the traditional two factor production models to the multi-factor production models. The latter models are capable of assessing the implications of rising factor prices on the derived demand for wood in the forest products industries.

Additional keywords: duality theory, cost function, restricted profit function, Zellner iterative 3 sls, maximum likelihood estimation.

INTRODUCTION

Most of the empirical studies of production processes in the forest products sector have been concerned with homogenous and additive production structures, such as the CES and the Cobb-Douglas functions. Both of these functional forms are restrictive in the sense that they have a build-in assumption of constant elasticity of substitution between factor inputs. In the particular case of the Cobb-Douglas form the constant is constrained to equal unity. When only two factors are present, the CES form, unlike the Cobb-Douglas, allows for the estimation of a single elasticity of substitution. With three or more factor inputs there are several partial elasticities of substitution to consider, and to assume them all equal is to miss some important economic phenomena.

The technology of a production process defines the technical means whereby inputs are combined to produce one or more outputs. In the economic theory of production, the technology of a firm or industry is described by a production function of the general form, such as

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(1) $Q = f(X_1, X_2, \ldots X_n; T)$

which is a mathematical representation of the minimum input $(X_1, X_2, \ldots X_n)$ requirements to produce any given level of output (Q), given a specific state of technology (T). In other words, the production function expresses the relationship between the maximum output obtainable under a fixed technology for given quantities of inputs, as well as the relationship between the factor inputs themselves, with the objective of displaying the substitution between the factors of production to achieve a given level of output. There are three important parameters that describe the properties of a production technology of a firm or an industry, namely:

1. The Allen-Uzawa partial elasticities of substitution between pairs of inputs. They measure the ease of substitution of inputs in the production of a fixed level of output.

2. Returns to Scale, which measures the economies or diseconomies of scale. It is the proportional change in output for a simultaneous equiproportional change in all inputs.

3. Technological change and bias. Technological change is defined as an inward movement in input space of the production - isoquant frontier. For a given set of inputs, technological advancement permits the production of a larger quantity of output than would have been otherwise attainable. Technological change may be biased both with regard to the factor inputs and with regard to the scale characteristics of the production process (See Stevenson, 1980). With regard to factor input biases, Hicks defined technological change as being neutral if the marginal rate of technical substitution between each pair of inputs is independent of technological change. With respect to scale characteristics of a production process, Stevenson stated that "Such a bias would alter the range over which returns to scale of a given degree could be realized - and thus possibly alters the output level at which minimum average costs could be attained".

To be able to estimate the above three parameters, it is necessary to specify a functional form for equation (1). Studies such as Manning and Thornburn (1971) and Robinson (1975) of the Canadian and U.S. forest products industries employed the two input Cobb-Douglas Production function of the form

(2) $Q = TL^{\alpha}K^{1-\alpha}$ $\qquad o<\alpha<1$

in which they assumed constant returns to scale, unitary elasticity of substitution, and Hicks neutral technological change. Although, the assumption of constant returns to scale may be reasonable at the industry level the other two assumptions are technically unjustifiable and should be statistically tested for their validity. This approach does not allow the estimation of the effect of changes in input prices other than the labor (L) and capital (K). For example, the rapid increase in energy prices is not accounted for in this two-input production function. Recent development of flexible functional forms along with the application of duality principles allow the estimation of non-restrictive substitution characteristics of production structures containing many inputs.

Two approaches are hereby reviewed, the cost function approach and the restricted profit function approach. Methods of implementing these approaches in the forest products industries are also given.

THE COST FUNCTION APPROACH

i) Duality theory and the cost function

Diewart (1973) discusses the Samuelson-Sheppard original duality theory and its application. Briefly, this theory purports that, if the firm's objective is to minimize costs, then under certain regularity conditions, duality exists between the production function and the cost function. Furthermore, different regularity conditions on the production function give rise to different regularity conditions on the cost function, i.e. a one-to-one correspondance exists between the production function, which is defined on the space of input quantities, and the cost function, which is defined on the space of input prices.

Using this approach, the modeller assumes, in the particular industry being studied, that there exists a continuously twice differentiable, strictly monotone, and strictly quasi-concave aggregate production function relating the flow of gross output (Q) to the services of n inputs (usually n is four inputs: Capital (K), labor (L), energy (E) and other intermediate materials (M)). Corresponding to such a production function the modeller assumes the existence of a dual cost function reflecting the production technology. Assuming that the producer's objective is to minimize costs and that output quantity and input prices are exogenous, the implicit form of this dual cost function is written

(3) $$C = g(Q,P_K,P_L,P_E,P_M;T)$$

where C is total cost, P_K,P_L,P_E and P_M are the input prices of K, L, E and M respectively; and T is the time specific state of technology. An advantage of using a cost function rather than a production function is the direct derivation of the input demand equations that are functions of all input prices as well as the output level. The derived demand equations are obtained by employing Shephard's lemma which states that along the minimum cost expansion path, the equilibrium employment of the ith input is given by

(4) $$X_i(Q,P_K,P_L,P_E,P_M) = \delta C/\delta P_i \quad ; \; i = K,L,E,M$$

Although the derived demand equations are of interest in themselves, they allow the estimation of the Allen-Uzawa partial elasticities of substitution (AES) and the demand price elasticities of factors of production The partial elasticities of substitution σ_{ij} and the price elasticities of demand E_{ij} are defined by

$$(5) \qquad \sigma_{ij} = (\delta^2 C/\delta P_i \delta P_j) C / (\delta C/\delta P_i)(\delta C/\delta P_j)$$

$$E_{ij} = \delta \ln X_i / \delta \ln P_j$$

which implies that σ_{ij} and E_{ij} are functions of the inputs $(X_1,..,X_n)$ and the parameters of the cost function C. Allen (1938) has shown that the AES are analytically related to the price elasticities of demand for factors of production in the form

$$(6) \qquad E_{ij} = S_j \sigma_{ij} \quad \text{, where } S_j \text{ is the cost share for } j$$

To estimate the demand equations (4), it is necessary to specify a parametric form for the cost function (2). The modeller has a wide range of choice among the flexible functional forms that have been developed and tested recently in many studies in the U.S. and Canadian manufacturing sectors (See Denny (1978) for a list of references to these studies). These functional forms are flexible in the sense that they provide a second order approximation to an arbitrary cost function, which satisfies the regularity conditions mentioned above, they also place no *a priori* restrictions on the AES. Among these forms are the generalized Leontief (GL) and the generalized square root quadratic (GSRQ) that were proposed by Diewart (1971) and (1974) respectively, and the translog (TLOG) that was initiated by Christensen et al (1973). The analyst may arbitrarily choose any one of these forms to specify the cost function. For example, Stier (1980) and Sherif (1981) arbitrarily chose the TLOG to specify their cost function. On the other hand the approach developed by Berndt and Khaled (1979) may also be followed. This approach made use of Khaled's (1978) proposed generalized Box-Cox (GBC) functional form that takes on the GL, GSRQ and TLOG as limiting cases. The nonhomothetic GBC cost function with disembodied technical change and linear homogeneity in prices is shown to be of the form

$$(7) \qquad C = \{(2/\lambda) \sum_{ij}\sum \gamma_{ij} P_i^{\lambda/2} P_j^{\lambda/2}\}^{1/\lambda} Q^{\beta(Q,P)} e^{T(t,P)}$$

where P_i is the price of input i, t is time,

$$\beta(Q,P) \equiv \beta + (\theta/2)\ln Q + \Sigma \phi_i \ln P_i$$

and

$$T(t,P) \equiv t(\tau + \sum_i \tau_i \ln P_i)$$

By assumption $\gamma_{ij} = \gamma_{ji}$ Linear homogeneity in prices requires that $\Sigma\tau_i = o$ and $\sum_i \phi_i = o$ for all i (For further discussion see Berndt and Khaled (1979). The limiting cases of the GBC form depend on the value of λ. They show that if

$$\lambda = \begin{cases} 2 & \text{then GBC} \longrightarrow \text{GRSQ} \\ 1 & \text{then GBC} \longrightarrow \text{GL} \\ \lambda \to 0 & \text{then GBC} \longrightarrow \text{TLOG} \end{cases}$$

Therefore, when using the GBC form, λ is estimated along with the other parameters and its value could be statistically tested to discriminate among the various flexible functional forms. The advantages of using this approach, according to Berndt and Khaled, is that it allows simultaneous estimation of the substitution elasticities, scale economies and the rate and bias of technical change. Also, total factor productivity is estimated parametrically rather than being computed as the residual of growth in outputs minus growth in inputs. This method is definitely more complicated than the former, but it is worth the effort (given the availability of data) since empirical results could vary substantially depending on the analyst's choice of a particular flexible functional form.

ii) Empirical implenentation

Whether the analyst arbitrarily chooses a flexible functional form or uses Berndt and Khaled's approach to statistically discriminate between functional forms, the empirical implementation is the same. Estimates of the cost function parameters are obtained by the following steps. Choose a functional form for equation (2). Differentiate it with respect to the exogenous input prices and then employ Shephard's Lemma, which yields n demand equations for factors $(X_1,\ldots,X_n)$ in the GL, the factor share demand equations in the TLOG, or the input-output equations in the GBC. These equations along with the cost function form a system of simultaneous equations. Since cost minimization behaviour is not practiced in any exact sense by producers, an additive disturbance term e_i is included in each equation. Under the assumption that the vector

$$e_t = (e_{1t}, e_{2t}, \ldots, e_{nt})$$

is temporally independent and contemporaneously correlated, it is necessary to estimate the factor demand equations simultaneously to gain more efficiency. Zellner's "seemingly unrelated" multivariate estimation method is used in order to take into account the restrictions imposed on the parameters caused by the linear homogeneity in prices assumption and the comtemporaneous correlation across equations. In the case of a TLOG specification, the adding up criterion of the share equations $(\sum_i s_i = 1)$

causes the variance-covariance matrix of disturbances to be singular. Thus it is necessary to drop one of the demand share equations and use Zellner's iterative three state least squares (I3SLS) method to obtain estimates that are invariant to the equation dropped. (See Sherif (1981)).

This estimation procedure uses time series data, cross section data, or pooled time series cross section data, on the input prices and output quantities. In the case of the GBC input-output data are also required. A common problem that may face the analyst especially with time series data is the multicolinearity problem that is the result of the inadequate variation in factor price data. One way of solving this problem is to reduce the number of inputs to four or less by imposing *a priori* the restriction that the production structure is weakly separable in the major categories of labor, capital, materials and energy (Fuss (1978)).

THE PROFIT FUNCTION APPROACH

i) The duality between profit functions and production functions.

The cost function approach is usually applied to a single output multiple input firm or industry. The existence of multiple products that are sold in markets of differing structure and produced under different technological conditions, is dealt with by measuring gross output Q by an aggregate index of production. This method implies that all the products are perfect substitutes for one another. Furthermore, the cost function approach treats all inputs as variable, which is not the case in the short run where some inputs may be predetermined.

Lau (1976) has shown that there is a one-to-one correspondence between production functions and normalized restricted profit functions under alternative set of conditions. Therefore, the analyst may just as well start with the appropriate normalized restricted profit functions. Lau defines the normalized restricted profit function as the maximum value of the normalized profits given the values of the normalized prices of the variable commodities and the quantities of the fixed commodities. A commodity can be either a net output or a net input. Each commodity is measured as if it were a net output. Thus, if the quantity of a commodity is positive, it is a net output; if the quantity is negative, it is a net input; if the quantity is zero, it is neither a net output nor a net input.

Using Lau's terminology, consider a multi-product firm producing in the short run (a period of time during which some inputs and outputs are predetermined), let there be (n+1+m) commodities. The first (n+1) commodities, denoted $y_1, y_2, \ldots y_{n+1}$ are taken to be variable, i.e., the firm is free to adjust their values; the last commodities, $k_1, k_2, \ldots k_m$

are assumed to be fixed. All prices are measured relative to the price of the (n+1) first commodity. The price of y_{n+1} is always one. Thus the price system is referred to as the normalized price system, and the prices as the normalized prices. The normalized price of the variable commodities are denoted $y_1^*, y_2^*, \ldots, y_n^*$, the normalized prices of the fixed commodities are denoted $k_1^*, k_2^*, \ldots, k_m^*$. Thus the normalized restricted profits, shown as

(8) $$P = \sum_i y_i^* y + y_{n+1} \qquad i = 1,\ldots,n$$

are defined as the sum of the values of net outputs in terms of the numeraire commodity. The maximized value of P, for given $y^*=(y_1^*,\ldots y_n^*)$ and $k=(k_1,\ldots k_m)$ is the normalized restricted profit function $\pi(y^*,k)$ where *

(9) $$\pi(y_i^*,K) = \sup_y \{\sum_i y_i^* y_i + y_{n+1}\} \quad , \quad i = 1,\ldots,n$$

ii) Empirical implementation

The analyst assumes that the producer maximizes profits subject to the constraint of his production possibilities set. Then, specifies a functional form for $\pi(y^*,k)$ which should be convex, homogeneous of degree one, a function of the prices of variable inputs, and exhibits diminishing returns to scale in the variable inputs. In addition, this form should be differentiable with respect to variable output and input prices. Diewart (1973) discusses an array of functional forms for $\pi(y^*,k)$ including the GL and TLOG function. Lau (1976) favored the quadratic functional form. Muller (1979), following Lau, tested the quadratic functional form in his study of the Pulp and Paper industry in Canada.

Having assumed that the producer is a price taken and decided on a functional form for $\pi(y^*,k)$, the analyst then, via Hotelling's Lemma (See Diewart (1973)), obtains the system of derived demand of factors and supply of outputs functions by differentiating $\pi(y^*,k)$ with respect to y_i^*. The system of derived demand and supply equations obtained above is then estimated using the same methods discussed above in the cost function approach. These equations, when estimated, will provide estimates of own and cross-price elasticities of factor demand and of product supply, as well as the partial elasticities of substitutions.

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* Supremum is used rather than maximum because there may be an upper bound to normalized restricted profits which is not attainable by any finite production plan.

CONCLUDING REMARKS

The principle purpose of this paper has been an attempt to review two alternative approaches for estimating the production technology in the forest products industries. No judgement of these approaches was intended, and the analyst should decide on which approach is more appropriate for his/her case study.

These approaches place no *a priori* restrictions on the production technology of an industry, such as constant elasticities of substitution, constant returns to scale, Hicks neutral technological change or homotheticity assumptions. However, some assumptions are still required to obtain estimates of the parameters describing the technology of an industry, e.g. cost minimization behavior, price taking behavior and profit maximization behavior of the producer. The analyst should be willing to accept these assumptions as a first approximation to real world behavior.

One advantage of implementing these approaches is their ability to estimate separatly the impact of delivered wood cost, labor compensation, capital equipment and construction prices, and purchased energy prices on forest industry production costs. They represent the state-of-the-art in econometric methodology and, to my knowledge, have not been implemented in any of the national or regional forest sector models reviewed in the IIASA Forest Industry Study.

An important problem that will face the analyst when implementing these approaches, is the availability and reliability of the data required for such models. However, an analyst who is concerned with building an econometric model for the forest industry sector, that is capable of assessing the influences of factor costs (especially labor, energy and capital), environmental regulation, or transportation costs on the development and shift of processing facilities for forest products, should make the effort to develop the necessary data base for such a model.

Finally, I would like to refer the reader to Diewart's (1973) concluding comments, where he discusses briefly how to choose among the different approaches and functional forms depending on which behavior the analyst is willing to accept.

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METHODS OF ANALYSIS OF BILATERAL AND MULTILATERAL TRADE AMONG MAJOR FOREST PRODUCT TRADING PARTNERS

David R. Darr

Abstract. --This paper provides a review of literature of methods of analysis of trade patterns. The needs of the U.S. Forest Service for analysis of trade in timber products are described. Current research of the U. S. Forest Service to model trade in timber products is reviewed.

INTRODUCTION

There is a well-developed body of literature dealing with the general problem of analysis of bilateral and multilateral trade. Applications of available methods of analysis have been limited in the forestry sector. The U.S. Forest Service has some specific and, in many respects, unique needs for modeling world trade in timber products. Research is underway to refine the approach used by the U.S. Forest Service in projections of trade in timber products.

This paper is organized to review selected literature on methods of analysis of bilateral and multilateral trade; to point out the needs of the U.S. Forest Service for analysis of trade in timber products, and to describe the direction of research underway to improve the ability of the U.S. Forest Service to model trade in timber products.

LITERATURE REVIEW

The general theory of bilateral and multilateral trade is discussed in most texts on international trade, e.g. Kreinin (1971), Much of the literature on analysis of trade patterns could be classed as estimation of elasticities of price and income for demands for imports and exports and large-scale modeling of economies and markets.

Leamer and Stern (1970) point out some of the problems in trying to estimate the price and income elasticities of demands for imports and exports. There have been numerous applications to estimation of elasticities for broad, aggregate categories of commodities, e.g. Kreinin (1967), Houthakker and Magee (1969), and Adler (1970). There have also been applications to agricultural products, e.g. Sirhan and Johnson (1971) and Johnson (1977).

The purpose of research on estimation of elasticities has been generally to estimate the responses of quantities of imports or exports to changes in prices and incomes. Statistical problems have apparently limited the research in this area, especially for disaggregated commodity groupings.

There are numerous ways to classify the literature dealing with large-scale modeling of the behavior of markets. For example, studies could be classed according to the techniques used in the analysis, the type of situation being analyzed, the geographic area of the analysis, or the commodity being analyzed. Possibly the most general differentiation of models would be between national and commodity models. National models attempt to relate aggregate measures of the economy such as savings, investment, and money supply to projection of prices or other variables of interest. Commodity models relate the supply and demand for a specific commodity or commodity group to underlying variables such as costs of production and personal income.

The Wharton model and the Data Resources model are examples of national models. In these national models, imports and exports may be represented as aggregates for all commodities. Work has been done, however, in attempting to integrate commodity models into national models (Adams 1978). Perhaps the best known attempt to link national models is project LINK (Ball 1973, Adams 1978). Problems of balancing imports and exports among counties have been major stumbling blocks to successful linkages of national models.

Labys (1973, 1975) provides a guide to the literature on commodity models through his taxonomy of these models. There are literally hundreds of applications of various techniques to the problems of modeling markets for commodities (Labys 1978A). Labys (1975) differentiates among models by type of methodology used in the analysis. Models may be differentiated as being market, process, input - output, spatial equilibrium, recursive programing, industrial dynamic - dynamic commodity cycle, systems or resource base. The more familiar applications would probably fall under the headings market model and spatial equilibrium model.

Specifications of the various models vary in terms of how imports and exports are handled. In part, specification of the trade sector of a commodity model depends on the objective of the analysis and in part on the availability of data. In general, the objectives of commodity models have been to project the values of variables such as production and prices or to display the consequences of alternative policies.

Just as models of the national economy may not have commodity models as components, commodity models rarely have endogeneous linkages to national models. Penson and Hughes (1979) have proposed a framework for linking a model of the agricultural sector with financial markets.

Of the various methodologies for modeling commodity markets, spatial equilibrium models in concept are probably the most straight forward in generating multilateral trade flows. Trade flows calculated with an unconstrained model may not trace out actual patterns of trade, however. For example, in an application to world flows of wheat, Shei and Thompson (1977) speculated that factors not considered explicitly in their model may have accounted for unexplained trade patterns depicted by the model. For example, wheat is not a homogenous product and bilateral agreements can influence trade flows.

When trade is considered in commodity models, it may be on a bilateral basis, as between the United States and Canada. An alternative approach has been to view trade as being between the United States and the rest of the world.

In national models, trade in some commodities may account for so little of total national activity that variations in the domestic economy mask any linkages of trade in the commodity to the national economy. Similarly, for some individual commodity models, trade may have little effect on the industry. The vagaries of some trade patterns may defy modeling.

To date, the projection of world-wide equilibrium trade flows in timber products has been based on judgment rather than an explicity, quantified model. These judgments have implicit within them, however, assumptions about excess supply, excess demand, and other components of a framework for analysis of trade. A study by an FAO working group is perhaps the most comprehensive example of projection of world trade flows on a judgmental basis (FAO 1979).

McKillop (1973) and Gallagher (1980) have done work on estimation of models of U.S. - Japanese - Canadian trade in logs and lumber. Adams and Blackwell (1973), Mills and Manthy (1974) and Robinson (1974) in various ways accounted for U.S. imports of softwood lumber from Canada and U.S. exports of logs from the west coast in models of U.S. markets for softwood stumpage and softwood lumber. Adams (1974) modeled U.S. log exports as a component of a model of the stumpage market in the Douglas-fir region.

A model by Data Resources Inc. (1980) models U.S. imports of softwood lumber from Canada as a component of an overall model of the U.S. timber industry. The Timber Assessment Market Model (TAMM) which has been described to you has as an endogeneous component Canadian exports of softwood lumber to the United States (Adams and Haynes (1980).

Buongiorno, et al (1979) estimated various one-equation models of Canadian exports of softwood lumber to the United States. His purpose was to estimate the elasticity of these imports with respect to U.S. housing starts and other variables.

In summary of the forestry literature, analysis of trade in timber products has been limited. Some work has been done on modeling exports of softwood lumber from Canada to the United States and U.S. exports of softwood logs to Japan.

Offshore shipments from the United States and other world trade flows have been modeled only in the sense that judgments implicitly consider excess demand, express supply, and other components of a framework for analysis of trade.

The literature offers several directions that might be taken in efforts to model trade in timber products. There is not, however, an obvious approach that would meet the needs of all interests concerned about trade in timber products. As Labys (1973) points out, there are many aspects of the behavior of markets and methodologies vary in their abilities to model various types of market behavior. The approach to be taken in modeling trade in timber products thus depends in large part on the problems and concerns that are being addressed by the analysis.

THE RESOURCES PLANNING ACT AND MODELING OF TRADE

The Resources Planning Act of 1974 (RPA) (U.S. Laws, Statues, etc. Public Law 93-378) directs the Secretary of Agriculture and the U. S. Forest Service to conduct a Renewable Resources Assessment that must include an analysis of present and anticipated uses, demand for, and supply of renewable resources, with consideration of the international resource situation, and an emphasis of pertinent supply and demand and price relationship trends. The Act also directs that the Secretary shall prepare a Renewable Resource Program that would consider alternative national goals and alternative means to achieve these goals consistent with the findings of the Assessment. A fifty-year time horizon is required in making projections of supply and demand for the Assessment and for the analysis of programs that might alter supply and demand conditions identified in the Assessment. Long lead times are necessary for planning because of the long time period required to implement programs that might influence timber supply.

Thus, from the standpoint of the RPA, the concerns of the U.S. Forest Service about trade are primarily with analysis of alternative policies: Their effects on trade patterns and the effects of this trade on achievement of goals specified in alternative programs.

U.S. trade patterns

The direction of any modeling effort would depend in part on the trade flows to be modeled. Imports into the United States are dominated by Canada for pulp, newsprint, and softwood lumber and by Southeast Asia for hardwood veneer and plywood (Sedjo and Radcliffe (1980A). Key countries or regions of destination for U.S. exports are Japan for chips, softwood lumber, and pulp; the Common Market for softwood lumber, softwood plywood, pulp, and paperboard, and Canada for softwood lumber and pulp. Areas of growth in U.S. exports of timber products during the 1960's and 70's were pulpwood chips, softwood logs, softwood lumber, softwood plywood, and paperboard (Ulrich 1981).

For the purposes of responding to the terms of the Resources Planning Act, we need projections of how U.S. trade patterns might change in the future in the absence of any changes in policies and we need projections of trade patterns following any changes in policies. The need for these projections implies that we know or must somehow consider specific types of information about U.S. and other markets for timber products.

Information needs

In the past, the types of alternative programs considered by the U.S. Forest Service generally dealt in one way or another with the effects of changes in U.S. timber supply. For example, a program to intensify management of private forest lands might be one of the alternatives considered. The following discussion lays out the types of information that are implied as being needed to assess the effects of the program on U.S. and foreign markets for timber products. Although the discussion centers on the example of intensification of management on private lands, similar types of information would be implied as being needed to evaluate other programs that might affect U.S. timber supply.

If the United States is considered as an importer, the effect of the increase in domestic supply is to reduce (shift) the U.S. excess demand for imports. The net effect of the policy change on variables such as prices, U.S. production, and the U.S. trade balance would depend in part on the elasticity of foreign excess supplies of timber products in the U.S. market with respect to U.S. prices. In the case of U.S. imports from Canada, this implies that we can identify excess supplies of Canadian softwood lumber, pulp, and newsprint in the U.S. market. These excess supplies are dependent on total Canadian supplies of the products, total Canadian demands, and excess demands from offshore markets. The effects of the policy change would also depend on the elasticities of U.S. supplies of timber products before and after the change in policy and the elasticities of U.S. demands for these products.

If the United States is considered as an exporter, the effect of the increase in domestic supply is to increase (shift) the U.S. excess supply for exports. The net effect of the policy change on variables such as prices, U.S. production, and the U.S. trade balance would depend on the elasticity of foreign excess demand for U.S. products. In the case of U.S. exports to Japan, evaluation of the effects of the policy change implies that we know something about Japanese excess demands for U.S. softwood logs, chips, pulp, softwood lumber, and potentially other products during the 50-year projection period. Knowledge of Japanese excess demands implies that we know something about Japanese supplies from non-U.S. sources and that we know something about Japanese demands for each timber product. To evaluate the change in policy and how it might affect exports, we would need to consider similar information about demands and supplies for other products in countries or regions of destination for U.S. exports.

There are other types of information that are implied by the effort to track timber supplies and demands during the 50-year projection period. The volumes and prices of end products rather than just roundwood equivalents of all trade need to be tracked through time to draw out the implications of the policy change. For example, a major concern in U.S. forest policy has been the price of softwood lumber and softwood plywood needed to meet U.S. housing goals. Lack of product specificity would limit our ability to draw implications from the projected supply-demand situation.

In projections, the roundwood producing sector would be linked to the processing sector. For example, there should be some means for keeping track of the total drain on the roundwood resource, whether or not the drain is due to solid wood products or fiber products. There should be some means of accounting for timber inventories through time.

The linkages among industries in the processing sector should be identified and considered in the analysis. For example, mill residue from lumber manufacture is used in pulp manufacture and this affects the demand for roundwood.

Within the United States, and possibly in other countries or regions, the analyses should be made at the regional level. For example, the potential of programs to intensity forest management on private lands in the United States varies by region. Also, the effects of foreign excess demands on U.S. markets vary by region within the United States. For example, producers on the U.S. west coast tend to be oriented toward Pacific Rim markets while producers in the U.S. south tend to be oriented to markets in western Europe.

Finally, there needs to be some way of forcing a balance of world supplies and demands for the various timber products. A solution "algorithm" would force consistency in the analysis. For example, it would ensure that a region could supply all of the product implied by demands projected on the region's resources. Preferably, this algorithm would be based on some notion of market equilibrium that would take account of prices and costs.

The list of information needs could be lengthened and made more specific. When projections of trade are made, the projections must implicitly or explicitly consider the types of information that have been discussed. Available information on timber resources and markets around the world suggests that we have a long way to go before we have the information base to model world trade in timber products in the detail that I have suggested. For example, only one third of the world's timber resources have ever been inventoried. Lack of inventory data makes it especially difficult to assess current and future prospects for the tropical forests of Southeast Asia (Myers 1980). Traditional sources of increased supplies in world trade may have reached the limits of sustained supply increases such as in the Soviet Union (North and Solecki 1977), British Columbia (British Columbia Ministry of Forests 1980), the U.S. west coast (Haynes and Adams 1979), and Southeast Asia (Sommer 1976). New sources of supply, especially New Zealand (Cavana and O'Day 1979) are developing potentials that could have major effects on world trade in timber products. We do not have a solid base of information to model markets and draw implications about the effects of these structural shifts in traditional trade patterns. Sensitivity analyses and normative analyses of markets under alternative assumptions about how markets should operate such as the work of Sedjo and Radcliffe (1980B) can help, but we are limited in our ability to model actual market behavior.

Current work of the U.S. Forest Service

The U.S. Forest Service has neither the budget nor the people to develop an intensive research program that would lead to large scale modeling of world markets for timber products. The following discussion describes our current direction for this type of research. The direction of the research is dictated in part by the needs of the 1984 RPA Assessment and Program.

The general terms of reference for this work are the following: 1. Projections of U.S. imports and exports of timber products to the year 2030 in the absence of significant changes in policies affecting domestic timber supplies and demands. 2. Development of the capability to model the responsiveness of U.S. trade in timber products to changes in domestic market conditions brought about through changes in policies affecting the prices of timber products in the United States.

For the 1984 RPA Assessment and Program, the starting point for assessing the consequences of alternative programs will be the TAMM. In its current version, all U.S. trade except imports of softwood lumber from Canada is exogenous to the model. The multilateral nature of U.S.-Canadian-offshore trade in softwood lumber is considered through judgments as to what Canadian and offshore demands might be during the 50-year projection period. Total exports of timber products are allocated by judgment to demand in the various supply regions of the TAMM. With the exception of imports of softwood lumber from Canada, imports are subtracted from total U.S. consumption. The model then solves for the regional allocation of U.S. production.

As has been discussed, the TAMM is undergoing extensive revision and the treatment of trade will be one of the revisions. Attempts will be made to fully integrate Canada into the TAMM so that U.S. imports of softwood lumber, pulp, and newsprint from Canada will be determined by the model. Offshore shipments from Canada will still be determined on a judgmental basis.

Imports of hardwood products into the United States will be determined on a judgmental basis.

Projections of exports in the absence of changes in policies will continue to be done on a judgmental basis as per the previous Assessment (United States Department of Agriculture Forest Service 1980). Consistency in judgments as to future trade patterns will be forced through an accounting framework that tracks annual consumption, production, and trade of major timber products by country or region of origin and country or region of destination. Emphasis will be given to markets in Japan and the Common Market countries. Product categories will include hardwood lumber, softwood logs and lumber, plywood, wood pulp, paper and board, and particleboard.

Attempts to model the responsiveness of U.S. exports to changes in domestic prices must somehow be linked to the TAMM. The TAMM provides the mechanisms necessary to trace the effects of trade through U.S. domestic markets. The approach that we are taking is to combine the output of the TAMM for product prices with the projections of trade volumes to be made on a judgmental basis. The following example for U.S.-Japanese trade in softwood lumber in the year 2000 demonstrates the approach.

In 1980, Japan produced about 30 million m^3 of softwood lumber and imported about 5 million m^3 (Forestry Agency of Japan monthly, Japan Tariff Association 1980). Some 1.5 million m^3 of Japanese imports of softwood lumber originated in the United States. The average value of imports from the United States was 45,084 Japanese yen per m^3. I expect Japanese imports of U.S. lumber to increase gradually over time, reaching 3 million m^3 in 2000. This level of consumption is assumed to be determined by the intersection of Japanese excess demand for U.S. lumber and the U.S.excess supply of lumber to Japan. The excess demand for U.S. lumber in Japan is determined by total Japanese demand for softwood lumber and supplies from sources other than the United States. The excess supply of U.S. lumber in Japan is determined by U.S. and other demands for and U.S. supply of softwood lumber.

If we now assume a change in policy in the United States such as intensification of management on private lands that affects U.S. supply, it has the effect of shifting U.S. excess supply in Japan and other markets.

To estimate the effect of the shift in U.S. excess supply on exports of lumber to Japan, we need the following: 1. Quantity of exports from the United States to Japan before the change in policy. 2. The price of U.S. lumber in Japan in 2000 before and after the change in policy. 3. The elasticity of Japanese excess demand for U.S. lumber with respect to price in 2000. This information can be used to construct an excess demand schedule for U.S. lumber in Japan and to locate shifts in excess supply in price-quantity space. The projections of trade volumes without a change in policy respond to point number 1. This amounts to 3 million m^3 in 2000. One of the outputs of the TAMM is the price of softwood lumber in various regions of consumption in the United States. We are proposing that an average price for U.S. lumber in the domestic market be used as the price of U.S. lumber in export markets. For example, the average real price for U.S. softwood lumber might be \$60 per m^3 in 2000. Following the change in U.S. domestic policy, the U.S. price might decrease to \$55 per m^3. We will assume that the price of U.S. lumber in Japan will also decline from \$60 to \$55.

We have several cooperative studies underway with the objectives of estimating the price-elasticities of demand for U.S. timber products in Japan and the Common Market. These studies have been underway only a short time and the potential for success is not clear at this time. For the purposes of carrying through the following example, an elasticity of -0.9 has been assumed for the Japanese excess demand for U.S. lumber in 2000. An elasticity (e) of -0.9, a price (P) of \$60 per m^3 and volume (Q) of 3 million m^3 would result in the following linear demand schedule.

$$e = \frac{Q}{Q} / \frac{P}{P}$$

$$\frac{Q}{P}(e) = \frac{Q}{P} = \frac{3,000,000}{60}(-.9) = -45,000$$

$$Q = A + \frac{Q}{P}(P)$$

$$3,000,000 = A + (-45,000)(60)$$

$$A = 5,700,000$$
$$Q = 5,700,000 - 45,000(P)$$

If a change in U.S. policy had the effect of lowering the price of lumber in the United States to $55 per m^3, U.S. exports would increase from 3 million to 3,225,000 m^3. The expanded exports from the United States would be linked back to the TAMM by allocating Japanese consumption to specific U.S. regions on a judgmental basis. Some iterations of the TAMM may be necessary to eliminate feedback effects of increased exports on domestic U.S. prices. Effects of exports on domestic U.S. markets would be displayed through the outputs of the TAMM.

The effect of lower U.S. prices on shipments from other supply sources would depend on the price elasticity of supply from each source. If, as appears to be the case, lumber from the various supply sources may be differentiated in the Japanese market, the effect of lower U.S. prices would also depend in part on the elasticity of Japanese excess demand for lumber from each source. For example, U.S. lumber may be differentiated from New Zealand lumber. A change in the price of U.S. lumber would act as a shifter on the Japanese excess demand for lumber from New Zealand. At the present time, we have no plans to try to trace the effects of changes in U.S. prices on shipments from other supply sources. This may prove necessary, however, as a check on the reasonableness of judgments about the elasticities of Japanese excess demands for U.S. products.

For Japan, we are proposing at a minimum that the analysis be done for softwood logs, softwood lumber and wood pulp. Some paper and board products may also be brought into the analysis.

The proposed approach should be considered as just a starting point in trying to model U.S. trade in timber products. From the standpoint of the U.S. Forest Service, it seems clear that what is needed is a means to simulate the behavior of world markets so as to evaluate the consequences of alternatives. Knowledge of the behavior of world markets for timber products is evolving over time. We expect that knowledge gained from our initial attempts at modeling world timber markets plus the work of others such as represented at this conference will provide a foundation for moving forward in this area of research. This will strengthen our ability to link effects on world timber markets with policies affecting the U.S. timber supply-demand situation.

OVERVIEW

This paper has concentrated on modeling and analysis of international trade in timber products as directed by the needs of the U.S. Forest Service. There are no major U.S. trade flows that could be termed bilateral. Our imports from Canada are determined in part by markets in Japan and Europe. Our imports of hardwood products are determined in part by trade among countries in Southeast Asia and by markets in Japan. Our exports to Japan are determined in part by events in Canada, the Soviet Union, and Southeast Asia. Our exports to Europe are determined in part by trade among countries in the region and by the course of Canadian supplies and demands for timber products.

Many structural shifts in world markets could be hypothesized as occurring during the next fifty years. Modeling of market behavior based solely on behavioral relationships derived from historical data is probably not a realistic approach to the problem of evaluating the effects of alternative policies. Judgments will be required as to the possible future courses of excess demands and excess supplies in world trade. Our current direction for long-term research in trade is oriented toward development of a simulation model that will incorporate available information plus judgments as to future courses of markets. This model may incorporate features from 1 or more of the available methodologies. The ultimate configuration of such a model would depend in large part on the needs of the U.S. Forest Service in terms of evaluation of alternative policies.

The needs of the U.S. Forest Service for modeling of international trade in timber products may be unique, especially the need for a projection period of 50 years. Available methodologies may be more or less appropriate for the modeling of trade to meet other needs. Much remains to be done in understanding world markets for timber products and in adapting available methodology to the modeling of these markets.

In this paper, the attempt to model the response of Japanese imports of softwood lumber to changes in U.S. prices points out some of the assumptions that need to be tested in further research. For example, elasticities of excess demand for U.S. timber products need to be developed. Relationships between export prices and domestic prices need to be examined in more detail to test the assumption that price changes in the U.S. domestic market would be reflected in price changes in the export market. The literature that has been cited in this paper needs to be better sifted for implications that might affect assumptions and other direction of further research on trade in timber products.

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CONCEPTS BEHIND IIASA'S FOOD AND AGRICULTURE MODEL

Michael H. Abkin*

INTRODUCTION

For the past several years, Michigan State University's Department of Agricultural Economics and, more recently, the U.S. Department of Agriculture's Economic Research Service have been collaborating with the Food and Agriculture Program of the International Institute for Applied Systems Analysis (IIASA/FAP) on the development of policy simulation models of U.S. food and agriculture as part of the IIASA/FAP global food and agriculture trade model. With this experience in mind, the objective of this paper is to summarize the concepts underlying the FAP model.

The paper begins with a brief discussion of the background and objectives of the project from both the IIASA/FAP perspective and the MSU and USDA perspectives. An overview of the FAP model system is then presented, including descriptions of its general characteristics, the algorithms used to solve national and global equilibria, and the basic linked system and detailed country models.

BACKGROUND AND OBJECTIVES

IIASA/FAP Problem Setting and Objectives

The Food and Agriculture Program began at IIASA in 1976 motivated by the following perceptions (excerpted from Parikh [1981]):

(a) Large numbers of people go hungry in the world today, although globally adequate food is available. This is true even in nations with adequate food on the average, because of improper distribution of income and food. (pg. 3)

(b) National policies are the important policies in dealing with the problem of hunger, either through increased production and/or through more equitable distribution. (pg. 8)

(c) Though national governments are the highest decision making bodies in the world, the interdependence of nations is critical in determining many national policy options. Trade in food and

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*Assistant Professor, Department of Agricultural Economics, Michigan State University, East Lansing, Michigan. Agricultural Economics Staff Paper No. 81-78. Paper prepared for presentation at the North American Conference on Forest Sector Models, Williamsburg, VA, December 2-4, 1981. The work reported herein is partially supported by Cooperative Agreement No. 58-3J22-0-00245 between Michigan State University and the U.S. Department of Agriculture.(d)The inherent uncertainty in agricultural production implies that even normally self-sufficient countries may need to depend on trade in exceptional years. (pg. 15) agricultural products forms a sizeable part of the total trade of many countries, and these countries are affected by the policies of other countries. (pg. 11)

(e) The agricultural sector is embedded in the national economy and should be treated in that setting. In most countries food and agricultural policies dominate economic policies, since food prices affect everyone in the economy. (pg. 16)

The conclusion drawn from these perceptions was that:

> . . . the present food problem is a problem of inadequate food consumption by a large number of people as a result of insufficient income and improper distribution, which is accentuated by uncertain climatic conditions, and which is amenable mainly to national policies, which are constrained by the actions of other countries. Thus the food and agriculture system of the world is best viewed as a set of national agriculture systems embedded in national economies affected by national governments' policies and interacting with each other. [Parikh, pg. 16]

Therefore, FAP's objectives are to (a) identify and evaluate the nature and dimensions of the world food problematique and the factors affecting it, and (b) suggest national and international policies to alleviate current food problems and to prevent future ones in both the intermediate and long runs. The analytical approach taken to achieve these objectives is development and use of a global general equilibrium simulation model composed of national models which interact with one another and respond to various government policy instruments and international agreements. The approach and models are described in a later section of this paper.

MSU and USDA Participation and Objectives

Michigan State University and the U.S. Department of Agriculture are motivated in this effort by similar perceptions from a U.S. perspective. It is clear from the experiences of the decade of the seventies that U.S. agriculture has become intimately tied to the world food and agriculture system and is likely to remain so for the foreseeable future. Policy actions and technological changes occurring in the U.S., whether domestically oriented or trade oriented, can have significant impact on other countries. Similarly, events occurring in other countries with respect to food supply and demand can greatly influence the prices facing our farmers and hence the well-being of our farm sector. Therefore, policy analysis in the U.S. should endogenize these global interdependencies.

Furthermore, recent debates concerning long-term resource constraints, land and water degradation and loss, and the direction that changes in farm structure are taking or should be taking are all testimony to the conviction that short-run forecasting and policy analysis is not sufficient for today's decisionmaking. That is, intermediate- and long-run views are also necessary to address the relevant policy issues.

Finally, the interdependencies between the agricultural and nonagricultural sectors in the U.S. are strong enough that, for longer-run analyses, ignoring them would miss a significant component of direct and indirect policy impacts. Included in these interactions are, for example, the price and availability of fuels, fertilizers, machinery and other agricultural inputs; the intersectoral competition for land, labor, and capital; and agriculture's important contribution to the U.S. trade balance and, therefore, overall national fiscal and monetary health.

IIASA/FAP's global general equilibrium approach offers the means by which U.S. food and agriculture policy analysis can be placed in the necessary international, intersectoral, and long-run context. Furthermore, the algorithms and overall model concept of the IIASA/FAP system are considered to be at the leading edge of the state of the art in this regard. Hence, the objectives of the MSU and USDA cooperative research are to (1) develop a detailed U.S. food and agriculture model which will a) be linkable to the IIASA/FAP system, and b) address the policy issues of interest to the relevant clientele groups in the USDA, elsewhere in the federal government, in state and local governments, in the research community, and in the private sector; and (2) transfer the IIASA/FAP basic linked system of country models with the trade linkage algorithms to the USDA for installation at the Washington Computer Center and use for projections and policy analyses.

THE FAP MODEL SYSTEM

This section presents an overview of the FAP model system, including discussions of the general equilibrium approach, the basic linked system and the international and domestic equilibrium algorithms. Equally as important to the success of the FAP approach as the technical aspects of the model is the structure of the project and its institutional relationships among country modelers and policymakers with FAP at the center. I will try to give a flavor of this in the discussion of the basic linked system.

General Equilibrium Approach

There are three concepts embodied in the "general equilibrium approach." First, it is general in that the system is closed with respect to countries, commodities, and money. That is, the whole world is modeled explicitly, as are all commodities and money. In this way, there are no infinite sources or sinks of goods and money to absorb policy impacts and mask feedback and other secondary effects.

The country and commodity definitions were selected in order to address the problem context described in the previous section. The specific countries and, in the case of the EC and the CMEA, country groups include the major food importing and exporting countries and were initially selected to cover about 80% of the world's population, land area, and production, exports, and imports of food (Table 1). Additional countries may be, indeed have been, added to the system depending on interest expressed by persons or groups within those countries. Closing the system, an aggregate rest-of-the-world model is included to endogenize the supply and demand of countries not specifically modeled (i.e., the other 20% of the world).

Two alternative commodity lists are considered in the model (Table 2.). The detailed list includes explicitly those commodities of primary concern in the world food problemand other commodities and commodity groups of importance to particular classes of countries. Again, the system is closed with an aggregatee nonagricultural commodity. The aggregate commodity list was defined to simplify initial model building and testing at IIASA of the basic linked system (described in the next section). Although it is still the operative list for the current version of the model, it is much too aggregated to exploit

Table 1 Countries in the IIASA/FAP System

1976 Percentages of World Total

Country	Population	Production	Land	Import	Export
USA	5.3	12.3	9.8	8.07	18.85
Australia	0.3	1.6	1.3	0.25	5.00
New Zealand	0.1	0.5	0.1	0.14	2.09
Canada	0.6	1.2	2.0	1.99	3.25
EC	6.4	11.9	3.3	38.83	26.05
Japan	2.8	1.8	0.4	8.36	0.05
Austria	0.2	0.4	0.1	0.62	0.31
Sweden	0.2	0.3	0.2	1.13	0.42
CMEA	9.0	16.7	17.5	12.72	5.74
Subtotal	24.9	46.7	34.7	72.11	61.76
Pakistan	1.8	0.9	1.4	0.34	0.34
China	21.4	13.2	17.3	1.64	1.81
Nigeria	1.6	0.5	1.6	0.50	0.40
Argentina	0.6	2.0	1.7	0.14	2.86
Indonesia	3.4	1.6	1.5	0.64	1.02
Mexico	1.5	1.5	1.3	0.35	0.82
Thailand	1.0	1.1	1.1	0.18	1.23
Brasil	2.8	4.7	4.0	0.75	5.55
Bangladesh	1.9	0.7	1.1	0.34	0.11
Egypt	1.0	0.7	0.3	0.94	0.56
India	15.5	6.7	14.6	1.06	1.30
Kenya	0.3	0.2	0.2	0.06	0.33
Subtotal	52.8	33.8	46.1	6.94	16.33
Total	77.7	80.5	80.8	79.05	78.09

Source: Parikh (1981), pg. 27.

Table 2

IIASA/FAP Trade Commodities

Aggregate Version	Detailed Version
1. Wheat (th. MT, grain eq.)	1. Wheat (th. MT, grain eq.)
2. Rice (th. MT, milled)	2. Rice (th. MT, milled)
3. Coarse grains (th. MT)	3. Coarse grains (th. MT)
4. Bovine and ovine meats (th. MT, carcass)	4. Fats and oils (th. MT, oil eq.)
5. Dairy products (th. MT, fresh eq.)	5. Protein feeds (th. MT, protein eq.)
6. Other meats (th. MT, protein eq.)	6. Sugar and products (th. MT, refined eq.)
7. Protein feeds (th. MT, protein eq.)	7. Bovine and ovine meats (th. MT, carcass)
8. Other foods (mi. $, 1969-71)	8. Pork (th. MT, carcass)
9. Nonfood agriculture (mi. $, 1969-71)	9. Poultry and eggs (th. MT, protein eq.)
10. Nonagriculture (mi. $, 1969-71)	10. Dairy products (th. MT, fresh eq.)
	11. Vegetables (mi. $, 1969-71)
	12. Fruits and nuts (mi. $, 1969-71)
	13. Fish (th. MT, protein eq.)
	14. Coffee (th. MT, bean eq.)
	15. Cocoa and tea (mi. $, 1969-71)
	16. Alcoholic beverages (mi. $, 1969-71)
	17. Clothing fibers (mi. $, 1969-71)
	18. Other nonfood agriculture (mi. $, 1969-71)
	19. Nonagriculture (mi. $, 1969-71)

Source: Abkin [1981], pg. 4.

the full potential of the IIASA/FAP system for policy analysis. Therefore, it is of high priority that the detailed list be implemented as soon as possible.

Even the detailed list, however, may not be detailed enough for some countries' purposes. Thus, although the international equilibrium, and therefore prices, will be determined at the level of one or the other of the lists in Table 2, a country model may be defined at a finer level of commodity detail. For example, Tables 3 and 4 show the definitions used in the detailed U.S. model for supply and demand commodities, respectively.

Secondly, the concept of equilibrium in the "general equilibrium approach" simply is that physical and monetary quantities must balance over the world for internal consistency. That is, in each year, net excess demand for each commodity, summed up over all countries, must be less than or equal to zero for a unique set of nonnegative world prices. In addition, the world price of a commmodity is zero when net excess demand for that commodity is less than zero (free disposal) and positive when net excess demand is zero. Furthermore, when this is true, then the world is also in monetary balance, with country trade balances adding up to zero.

It is in reaching equilibrium that the country components of the IIASA/FAP global system interact, as illustrated in Figure 1 for a four-country world. Each country is conceived to be composed of three basic components: (1) a production component, which depends only on governmnt plans and policies, lagged prices, and resource, environmental and technological changes; (2) an exchange component, which encompasses all parts of the country model (primarily demand and income accounting) that are determined simultaneously with prices, given supplies and government policies; and (3) a government component which adjusts plans and policies over time in response to socioeconomic conditions and changes taking place in the model. Those parts of supply which depend on concurrent prices -- such as nonagricultural and livestock commodities in the U.S. model -- are also considered to be in the exchange component. It is the exchange components of the national models that are all solved simultaneously (as indicated by the dotted lines in Figure 1) to determine world and domestic equilibrium prices and quantities.

Finally, while the concept of "general equilibrium" is relatively simple, the approach is certainly not. Since there are no unaccounted for sources and sinks in the model to take up any slack, rigid adherence to a complex set of economic conditions and mathematical theorems -- collectively called general equilibrium theory -- is essential for logical consistency. These have all been elegantly developed, complete with rigorous mathematical proofs, for the IIASA/FAP system [Keyzer, 1981], resulting in a "minimal" set of common characteristics each country model must possess in order to be linkable through the international equilibrium algorithm (described below). These linkage requirements include:

1) the country's net excess demand for each commodity must be a continuous function of, and homogeneous of degree zero in, world prices and money (although, since quota constraints are allowed, the first derivatives do not have to be continuous);

2) a common list of commodities and units of measure (Table 2) must be adopted, at least at the country's interface with the world; and

3) an annual time increment must be used.

Table 3

U.S. Model Supply Commodities

1. Wheat (th. MT)
2. Rice (th. MT, milled)
3. Corn (th. MT)
4. Grain sorghum (th. MT)
5. Oats (th. MT)
6. Barley (th. MT)
7. Rye (th. MT)
8. Soybeans (th. MT)
9. Peanuts (th. MT, shelled)
10. Sunflower (th. MT, seeds)
11. Flaxseed (th. MT, seeds)
12. Cottonseed (th. MT, seeds)
13. Cotton (th. MT)
14. Sugar cane (th. MT, refined)
15. Sugar beets (th. MT, refined)
16. Irish potatoes (th. MT)
17. Sweet potatoes (th. MT)
18. Dry beans and peas (th. MT)
19. Other vegetables & melons (th. MT)
20. Citrus fruits (th. MT)
21. Noncitrus fruits & nuts (th. MT)
22. Tobacco (th. MT, farm sales wt.)
23. Coffee (th. MT, beans)
24. Wool (th. MT)
25. Beef & veal (th. MT, carcass)
26. Lamb & mutton (th. MT, carcass)
27. Pork (th. MT, carcass)
28. Chicken (th. MT, R-T-C)
29. Turkey (th. MT, R-T-C)
30. Eggs (th. MT)
31. Milk (th. MT, fresh)
32. Fish (th. MT)
33. Nonagriculture (mi. $, 1972)

Source: Abkin [1981], pg. 5.

Table 4

U.S. Model Demand Commodities

1. Wheat (th. MT, grain eq.)
2. Rice (th. MT, milled)
3. Corn (th. MT)
4. Other grains (th. MT)
5. Soybeans (th. MT)
6. Peanuts & tree nuts (th. MT)
7. Fats & oils (th. MT, oil eq.)
8. Protein feeds (th. MT, soymeal eq.)
9. Sugar (th. MT, refined)
10. Other sweetners (th. MT, refined eq.)
11. Potatoes (th. MT)
12. Dry beans & peas (th. MT)
13. Fresh vegetables (th. MT)
14. Processed vegetables (th. MT)
15. Citrus fruits (th. MT, fresh eq.)
16. Noncitrus fruits (th. MT, fresh eq.)
17. Beef & veal (th. MT, carcass)
18. Lamb & mutton (th. MT, carcass)
19. Pork (th. MT, carcass)
20. Poultry (th. MT, R-T-C)
21. Eggs (th. MT)
22. Fresh milk (th. MT)
23. Cheese (th. MT)
24. Butter (th. MT)
25. Other dairy (th. MT)
26. Fish (th. MT)
27. Coffee (th. MT, beans)
28. Cocoa & tea (th. MT)
29. Alcoholic beverages (mi. liters)
30. Cotton (th. MT)
31. Wool (th. MT)
32. Tobacco (th. MT, leaf eq.)
33. Durables (mi. $, 1972
34. Services (mi. $, 1972)
35. Other nonagriculture (mi. $, 1972)

Source: Abkin [1981], pg. 6.

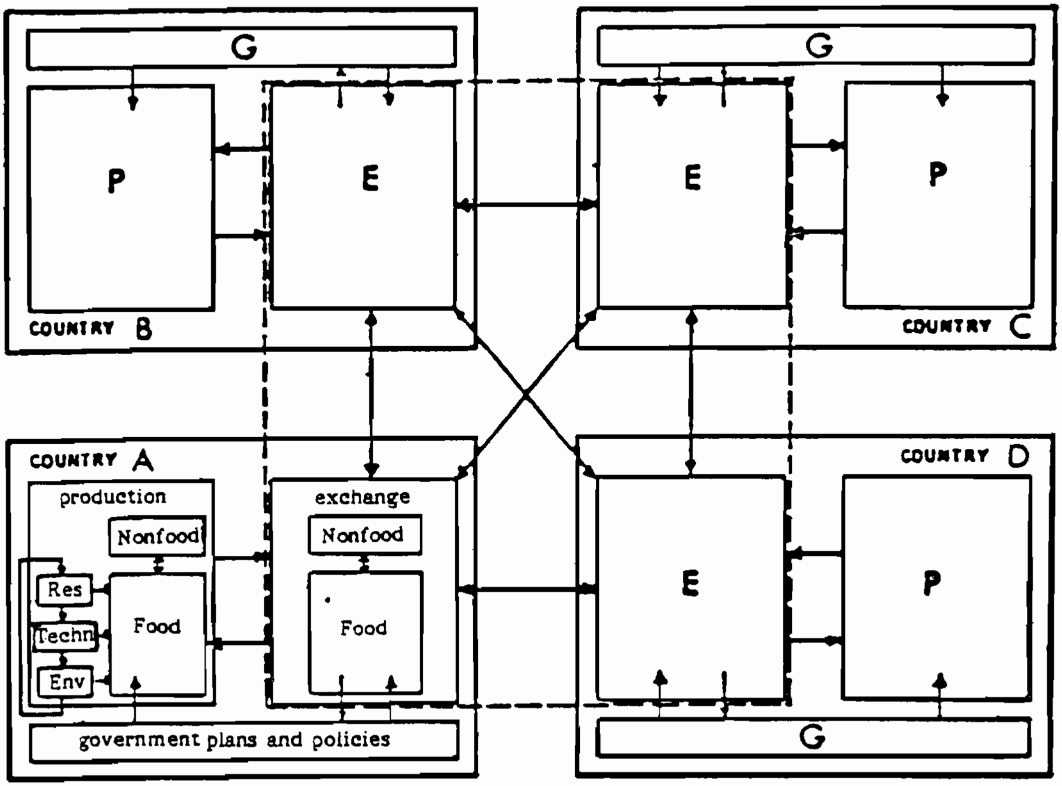

Figure 1

IIASA/FAP International Linkage

Source: Rabar [1979], pg. 8.

An additional requirement, more a result of the algorithm used than of economic theory, is that

4) each country model must compute an analytical (not numerical) Jacobian matrix of partial derivatives of net excess demand for each commodity with respect to each world price.

The algorithms used to implement this approach are described next, followed by a definition and discussion of the basic linked system.

Equilibrium Algorithms

As discussed above, the exchange components of all countries are solved simultaneously each year to find the global, or general, equilibrium. Nested, or hierarchical, iterative algorithms are used in this task, where the international algorithm is at the top of the hierarchy (the outermost iteration loop) and the domestic algorithm is at the bottom (the inner loop). Each of these will be briefly described here verbally to give a flavor of how the system works. Rigorous theoretical and mathematical derivations and specifications are given in Keyzer [1981, Chapters IV and VI].

International equilibrium. A coarse flow chart of the algorithm to achieve international equilibrium is given in Figure 2. Once the exchange component has been entered in a given year, world prices are set to their previous year's equilibrium value to start the iterations. Then, international policies for the current year are set. These are decisions made outside of the exchange equilibrium, i.e., they do not depend on prices in the current year. Such international policies as bilateral or multilateral trade agreements, buffer stock agreements, capital transfers, etc., may be considered. Next, the exchange component of each of the national models is solved in turn for its own domestic equilibrium net excess demand as a function of world prices and international policies. If all the domestic equilibrium net excess demands are consistent with world equilibrium, i.e., they all add up to zero at positive world prices, then the algorithm exits to solve the supply side of the country models for the next year. Otherwise, world prices are iteratively adjusted and the national models solved again until world equilibrium is reached.

The world price adjustments are made with the use of a nonsmooth optimization (gradient search) algorithm developed at IIASA [Lemarechal, 1978]. This algorithm is important because, while the excess demand functions must be continuous, their first derivatives may have discontinuities (i.e., the functions are nonsmooth), thus allowing for the use of quota policies.

Domestic equilibrium. The exchange component of each country model is solved at each iteration on world prices. The complementarity path algorithm described here (Figure 3) was developed by Keyzer [1981, Chapter IV) for the standard FAP models and used by most of the country models, including the U.S. Actually any algorithm may be used as long as convergence can be proved, the consistency linkage requirements are met, and the Jacobian matrix is computed.

First, any bounds which may be specified are set on domestic prices, buffer stocks, trade, and financial policies. These variables are also set to their target values to start the algorithm. These bounds and targets may be exogenously specified (either from

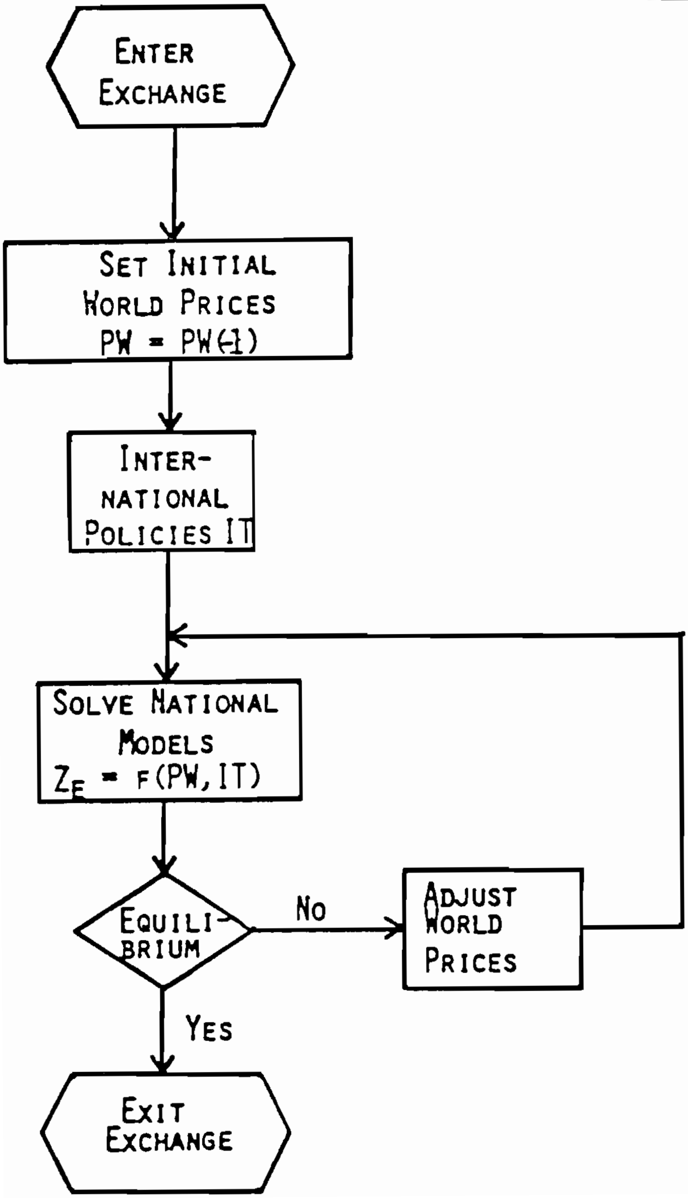

Figure 2

International Equilibrium

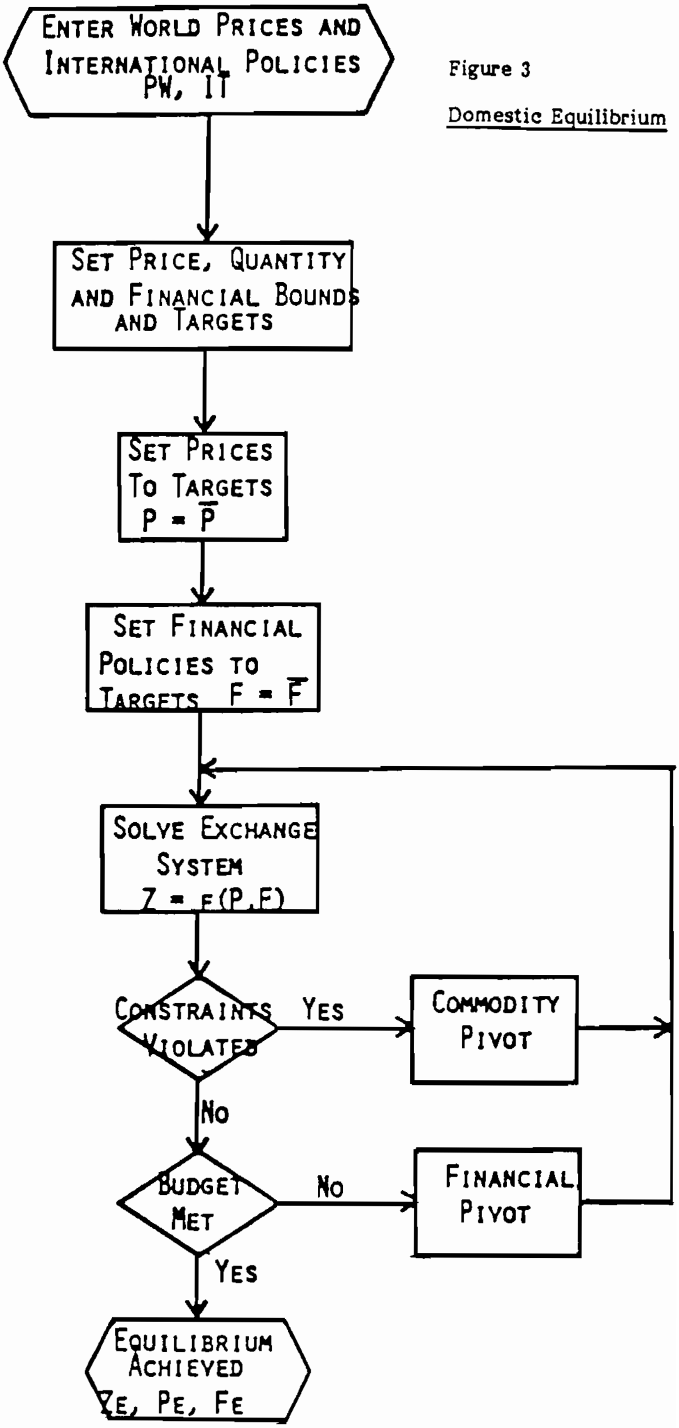

Figure 3

Domestic Equilibrium

outside the model or based on lagged conditions) or be computed as functions of world prices.

The concept of price "targets" may be interpreted as actual policy targets or merely as a relationship between domestic and world prices, including any tariffs or subsidies. In any case, however it may be interpreted, these target prices will turn out to be the domestic equilibrium prices if no quantity constraints are effective.

With prices and financial policies (tax rates, public consumption, and trade balance) set to target values, the supply-demand exchange system is solved. If any quantity constraints (quota or stock) are violated, the system is inverted ("commodity pivot") for those commodities to solve for prices which will put the associated quantities at their constraint values. When all quantity constraints are satisfied, and if the national budget is met, the domestic equilibrium has been achieved in terms of equilibrium prices, financial policies, and net excess demands.

If the budget is not satisifed, financial policies are adjusted to achieve that end. These adjustments are made in a hierarchical fashion, where lower priority policies are adjusted first and higher priority policies are adjusted only if lower priority ones have reached a bound. The priority ranking, targets, and bounds on tax rates, public consumption, and the trade balance are specified as policy parameters by the user exogenously or as functions of lagged conditions in the model.

Basic Linked System and Participating Institutions

In IIASA/FAP parlance, the "basic linked system" is the international linkage mechanism (i.e., the world superstructure) together with the set of basic country models which plug into that superstructure.

There may be up to two models of a country -- a basic model and a detailed model. All countries specifically included in the system have at least a basic model. A country's detailed model will tend to be more disaggregated with respect to, for example, commodities, regions, income classes, policy instruments, resources, technology, etc., as appropriate for that country. In using the system for a particular analysis, then -- such as bilateral or multilateral agreements among particular countries, or impacts of one country's policies on particular other countries -- the detailed models of only those countries of direct concern need be used, with use of the basic (generally simpler) models of other countries being sufficient for the task at hand.

There are two or three types of basic country models. FAP itself developed a prototypical country model whose common structure has been replicated for most of the FAP countries, with parameter estimates for each country derived primarily from FAO data [Fischer and Frohberg, 1980]. These models are called "standard FAP country models" and comprise most of the basic models in the system. For a few countries, country modelers have developed their own basic models. In some cases, these have used the FAP standard model as a point of departure, eventually replacing it. In others, as MSU has done for the U.S. basic model, a model of intermediate complexity has been developed both to serve as a basic model and to gain experience before tackling the detailed model. In one case, that of India, the detailed model is also used as the basic model.

A vital facet of the IIASA/FAP approach is the creation of a network of participating institutions all over the world developing models of their countries which will all be mutually consistent and executable on a computer for joint analyses. In this regard, FAP's standard basic models have proven very effective in orienting new country modelers to the project, the modeling approach, and the linkage requirements. That is, new groups may begin their participation by first examining the structure and evaluating the operation of the FAP standard model for their country. They may then reestimate it using their own country's data rather than FAO's and possibly make other modifications, resulting in an improved basic model for that country -- at least improved in the eyes of interested parties in that country, which is important for the international cooperation among researchers, analysts, and policymakers necessary for the FAP objectives to be ultimately achieved. Once familiarity with, and some degree of confidence in, the structure and requirements of the IIASA/FAP system has been thus attained, participating groups may then proceed to the development of detailed country models.

Another aspect of the distinction between basic and detailed country models has emerged in the recent FAP policy statement on the distribution and use of the system. That is, participating institutions, such as MSU and USDA in the U.S., are entitled to receive copies of updated versions of the basic linked system, including the linkage superstructure, the set of basic country models, and associated data files, in return for updated versions of the basic or detailed model developed by that institution. The public version of the detailed country models residing at IIASA are not to be distributed automatically to other participating institutions, as is the basic linked system, but are to be used at IIASA for joint analyses, with further distribution at the discretion of the participating institutions supplying them.

CONCLUSIONS

The FAP model system is currently operational on the VAX computer at IIASA, and we are in the process of transferring a copy of it to the CDC and IBM computers at MSU and USDA. The system was used recently for a study IIASA/FAP did for the OECD. This is not to say the system is "final". No model, if it is to remain relevant and useful, can be considered final or complete. In the case of FAP, the IIASA team has its work cut out for it not only to maintain and use the model system but also to continue to extend and improve it in a number of important ways (such as disaggregation to the detailed commodity list of Table 2, mentioned earlier) and to maintain and expand the international network of participating institutions it has created.

The concepts behind the FAP model system have a great deal to offer those interested in modeling and analyzing other sectors, such as in being considered by IIASA for the forestry sector. From the FAP perspective, application to other sectors would represent a much-needed disaggregation of the nonagricultural commodity. For forestry purposes, too, it may be desirable to further break down nonagriculture to consider important inputs, processing, and substitute sectors. It may also be necessary to consider some disaggregation of agriculture -- although probably not at the levels indicated in Table 2 -- to capture the important interactions between forestry and agriculture. In any case, the FAP approach can be usefully applied to forestry or any other sector where international trade is important and where national policies should be analyzed in a general equilibrium framework so as not to miss important feedback and other indirect impacts.

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APPROACHES TO THE MAJOR PROBLEMS OF MODELING FREIGHT COSTS AND OTHER PRACTICAL FACTORS

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Abstract.--This paper presents the preliminary estimates of ocean freight cost functions for selected forest commodities. The models explain both differences in rates for different forest commodities on the same trade route, and differences in rates for the same commodity on different routes. The source of data for estimating the models is the tariff schedules posted by shipping companies with the U.S. Federal Maritime Commission. The results indicate that distance is the most important determinant of freight rates, followed by the unit value of the commodity, the total volume of goods shipped on a route, and the stowage factor of the commodity.

Additional keywords: forest products, ocean freight rates, transportation modeling, transport cost functions.

INTRODUCTION

The economics of ocean transportation of forest products has received very little attention in the forestry literature, despite the importance of transportation costs in influencing what forest products are traded, which countries trade, and the amount and direction of trade. This situation can be contrasted to the concern over the effects of resource endowment, production costs and import levies on forest products trade.

Both tariffs and transport costs act as barriers to trade. Both raise the cost of the imported product to the consumer, and both provide about the same level of protection to home industry. Recent studies have found that the level of protection provided by transportation costs is at least as great and, in many cases, greater than the protection provided by import tariffs (Finger and Yeats 1976, Sampson and Yeats 1978; Waters 1970).

One justification often given for the absence of research on transportation costs is that transportation costs reflect unalterable geographic factors and thus are not subject to policy control. This argument can be challenged by the counter-argument that transport costs are subject to a considerable degree of policy control through subsidies, economies of scale, modernization of port and fleet facilities, and so on (Binkley and Harrar 1981). In addition, recent research indicates that distance may be a less important factor in the level of transport costs than commonly imagined. As we shall see, other factors such as the unit value of the commodity, its

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bulkiness, port costs, and volume of trade are as important or more important than distance in determining freight rates. Policy-makers can influence these variables, and thus, can influence transportation costs between countries.

Without a sound understanding of the role of transportation costs, it is difficult to formulate intelligent trade policy, since the effects of tariffs and quotas can be confounded with those due to transportation. The lack of transportation cost functions also may seriously limit international trade research since differences in transportation costs can be one of the primary sources of comparative trading advantage among exporting nations (Binkley and Harrar 1981).

ECONOMICS OF OCEAN SHIPPING

The way freight rates are set is strongly influenced by the competitiveness of the shipping market. Tramps operate in a freely competitive market, and tramp freight rates tend to be strongly influenced by cost factors. The liner market is dominated by shipping conferences who operate as discriminating monopolists, and liner rates tend to be determined by demand factors rather than costs. However, most conferences are not perfect monopolies but are subject to competition from tramps and non-conference liners. Thus, liner rates for at least some cargo and routes are influenced by costs.

Conferences have adopted a value-of-service pricing policy, also commonly referred to as "charging what the market will bear." In practice, value-of-service pricing translates into charging high rates per ton on high-valued commodities and low rates on low valued commodities. Value-of-service pricing is a crude approximation of pricing according to a commodity's price elasticity of demand for transportation.

In practice, conferences are unlikely to have a clear idea of the elasticity of demand for the thousands of commodities shipped; nor are they likely to attempt to estimate these elasticities. Instead, they are likely to focus their attention on the relation between the freight rate and the landed value of the commodity, which is much easier to estimate. This leads to pricing according to value.

THE THEORETICAL MODEL

Previous Research on Ocean Freight Rates

The preceeding discussion of the economics of ocean shipping provides the background necessary for the development of a model of ocean freight rates for forest products. One of the earliest and most complete studies of freight rates was by the Economic Commission for Latin America (ECLA).

The ECLA study distinguished between the structure of freight rates and the level of rates. The analysis of rate structure relates to the reasons for differences among freight rates for different commodities on the same route. The analysis of the level of rates relates to differences in rates for the same commodity on different routes.

ECLA's rate structure model gave highly satisfactory results. Unit value and stowage were almost always significant variables and together explained a high proportion of freight cost variation among commodities. The level-of-rates model, on the other hand, gave much less satisfactory results. In general, the degree of explanation of rate variations was much less than for the structure model, and in many cases, unsatisfactory. For those commodities for which the model performed satisfactorily, three factors--the number of regular shipping lines serving a given route, distances, and costs in port--consistently emerged as the most significant explanatory variables.

The most significant conclusion of the study was that models explaining the level and structure of ocean freight rates can be relatively simple. The conventional wisdom had regarded the problem as one of exceptional complexity, since it had been assumed that the factors which may influence the determination of freight rates were too numerous to permit any generalization of the subject. The ECLA study showed that although there may be many factors that influence freight rates, only a few are necessary to provide a reasonable explanation. Thus, simple models can be used to estimate freight rates.

In general, subsequent freight rate studies support the findings of the ECLA study (Binkley and Harrar 1981, Bryan 1974, Chinitz 1959, Deakin and Seward 1973, Heaver 1974, Moneta 1959, Prewo 1978, Shneerson 1976). The weight of the evidence appears to be that two variables, unit value and the stowage factor are the key variables in explaining differences between freight rates for different commodities on a given route. With respect to differences in the freight rate of a single commodity on different routes, distance, competition on the route, and port costs are the most significant factors.

Empirical Models for Forest Products

The objective of my research is to develop a model, or models, that will explain the differences in ocean freight rates for different forest products on a given route, and differences in rates for the same product on different routes. That is, I wish to explain both the structure and level of freight rates for forest products.

Model I

Model I is designed to explain differences in rates among commodities on the same route. The principal demand variables are the unit value per ton of the commodity and the quantity of a commodity moved on a given route. The relationship between rate and unit value should be positive: commodities with high unit values will have high rates, and low-valued commodities will have low rates. The freight rate is expected to be inversely related to the volume shipped.

The only cost variable included in the model is the stowage factor. The quantity of cargo a ship can carry is determined by two factors: its measurement capacity and its weight capacity. The stowage factor in the model is an attempt to account for this relationship. The greater the stowage factor, the greater the freight rate per ton.

Model I can be stated in functional form as follows:

$$FR_{ij} = f(UV_i, S_i, Q_{ij})$$

where:

FR_{ij} is the freight rate of commodity i on route j in dollars/metric ton

UV_i is the unit value of commodity i in dollars/metric ton

S_i is the stowage factor for commodity i in cubic feet/metric ton

Q_{ij} is the quantity of commodity i shipped on route j, in metric tons.

Model II

Model II is designed to explain variations in the freight rate for a given commodity on different routes. The factors hypothesized to determine differences in rates among routes are distance, the quantity of the commodity shipped on the route, and the total volume of goods shipped on the route.

The freight rate is expected to vary directly with distance but in a less than proportionate manner. The variable, quantity-of-the-commodity-shipped is included for the same reasons as given for Model I. The total volume of goods shipped is a measure of competition on the route. It is expected that the greater the volume of goods shipped, the lower will be the rates.

Model II can be represented in functional form as follows:

$$FR_{ij} = f(DI_j, TV_j, Q_{ij})$$

where:

FR_{ij} and Q_{ij} are as before,

DI is distance of route j in nautical miles;

TV_j is the total volume of goods shipped on route j.

Model III is merely a combination of Models I and II, or:

$$FR_{ij} = f(UV_i, S_i, DI_j, TV_j, Q_{ij})$$

ESTIMATING THE MODEL

Source of Data

The most difficult part of developing ocean freight cost functions is the collection of data on ocean freight rates. There are basically three possible sources of information on freight rates. First, one can attempt to solicit the information directly from the carriers. Several of the studies cited obtained their data in this way. This approach is too costly under most circumstances.

Second, one might use the U.S. Department of Commerce report FT 135 to calculate an ad valorem transport cost. Report FT 135 lists U.S. imports both on a f.a.s. and c.i.f. basis. The difference between the two valuations is the implied cost of insurance and freight. However, it is well-known that measurement errors make these figures a questionable basis for econometric procedures (Geroci and Prewo 1977).

The third alternative is to use the tariffs posted in U.S. Federal Maritime Commission (FMC) offices by shipping firms and conferences trading with the United States. Unfortunately, it is no easy task to collect and tabulate these data. First of all, there is the matter of the physical location and form of the information. The tariffs are posted in individual loose-leaf holders and occupy two rooms in the FMC building. The tariff schedule of a single firm or conference may cover 300 pages, and one has to thumb through the entire document to seek out the forest products.

Once the appropriate data are extracted from the files, the task of transforming the information into a consistent data set begins. There is no standardization of terms or consistent use of units of measurement. On some routes, rates may be posted for very precisely defined commodities; on other routes only broad commodity classifications will be provided. Some firms may post special schedules offering volume discounts.

Despite these many difficulties, the FMC data remain the only reasonably accessible information on ocean freight rates short of a large-scale research effort. This source was used by the present study.

Preliminary Results

Several preliminary regressions have been run to test the data and to identify data problems. Only linear forms of the models have been tested, although it is anticipated certain of the variables should be stated in log form; for example, distance and unit value.

The regressions are based entirely upon non-conference liner rates. Conference rates have not yet been analyzed. It was concluded, after discussion with FMC officials and private tariff-watching experts, that non-conference liner rates more closely reflect actual market prices. Conference rates reflect the market power of the conferences and, in addition, posted liner rates do not reflect loyalty rebates offered by the conference. Only Model III, the combined-effects model, has been tested at this stage.

CONCLUSIONS

The most significant results of the preliminary testing of the ocean freight cost data are as follows:

1. In virtually every trial run, distance was the most significant variable. Unit value consistently was the second most important variable. Total volume of trade frequently was significant and usually had the correct sign.

2. The stowage factor did not perform satisfactorily in most cases. The problem probably stems from the lack of sensitivity of stowage factors to detailed commodity classifications.

3. In the cases where the volume of the commodity shipped variable was included it had the anticipated sign, but its significance was low.

4. Overall, the model performed the way one would expect. In those cases where the commodity was narrowly defined, the distance and total volume of trade alone were significant. As the number of individual commodities in the group increased, variables representing commodity characteristics became important. The order of entry tended to be: unit value, stowage and volume of the commodity shipped.

The preliminary tests appear to be consistent with the findings of other research on ocean rates, and indicate that it is possible to develop useful models of ocean freight costs for forest products.

The research I have reported upon at this meeting represents only a part of the problem of estimating freight costs for forest products. I have not touched upon a number of factors that have an important influence on the cost of trading in forest products. Some which come readily to mind are:

1. Overland freight costs. These costs not only influence the pattern of interregional trade but influence what products are traded on the world market and the intensity of trade.

2. Institutional factors such as the U.S. Jones Act may distort trade flows.

3. Inter-modal shipping complicates the estimate of total transport costs.

4. Reduced rates for cargo moving in-transit from-and-to inland points and ocean ports also complicates the estimating task.

5. A substantial portion of bulky forest products are shipped by tramps and owner-operated, specialized forest products vessels. Very little information is available on the cost of shipping for these vessels.

6. The cost of time-in-port and loading-and-handling varies by forest product and affect total tansport costs.

7. Containerships, roll on/roll off and LASH vessels are revolutionizing ocean shipping, and create difficult problems of cost estimation. Freight charges may be based upon the entire mill-to-market

haul, not just the ocean portion of the voyage. These rates are not fully comparable with port-to-port conventional liner rates.

8. The FMC data applies only to trade with the United States. Analyses similar to that reported above needs to be conducted for non-U.S. trade.

These are just some of the problems that remain to be resolved in modeling forest products transportation costs.

Preliminary Results of Estimating the Ocean Freight Rate Model

1. All commodities: U.S. to Europe

$$FR = -31.94 + .013DI + .049UV + 14.1475 \qquad R^2 = .50$$
$$(19.28) \quad (7.92) \quad (2.05) \qquad N = 435$$

2. Roundwood: U.S. to Asia

$$FR = -60.149 + .008DI + 47.1715 \qquad R^2 = .68$$
$$(7.10) \quad (4.07) \qquad N = 34$$

3. Lumber: U.S. to World

$$FR = -6.471 + .003DI + .293UV + .824TV \qquad R^2 = .56$$
$$(1.96) \quad (5.19) \quad (1.95) \qquad N = 43$$

4. Wood Panels: U.S. to World

$$FR = 189.111 + .006DI - 1.156TV - 47.356S \qquad R^2 = .62$$
$$(10.59) \quad (5.35) \quad (6.28) \qquad N = 165$$

5. Wood Pulp: U.S. to World

$$FR = 14.065 + .005DI + .104UV - .943TV \qquad R^2 = .46$$
$$(7.76) \quad (1.76) \quad (4.57) \qquad N = 146$$

6. Test of Q Variable, U.S. Gulf to World (Pulp)

$$FR = 46.857 + .007DI - .501Q \qquad R^2 = .49$$
$$(5.76) \quad (1.84) \qquad N = 36$$

7. All Paper Products: U.S. to World

$$FR = 213.427 + .008DI - .013UV - 1.498TV - 49.824S$$
$$(11.69) \quad (3.20) \quad (6.16) \quad (4.09)$$
$$R^2 = .36 \qquad N = 347$$

8. All Paper: U.S. to Latin America

$$FR = -31.820 + .016DI + .023UV + 33.108S \qquad R^2 = .55$$
$$(12.26) \quad (2.77) \quad (3.13) \qquad N = 131$$

9. Printing & Writing Paper: U.S. to World

$$FR = 94.672 + .009DI - 1.265TV \qquad R^2 = .33$$
$$(6.78) \quad (3.43) \qquad N = 120$$

10. Coarse Paper: U.S. to World

$$FR = 33.589 + .009DI + .061UV - 10.167TV \qquad R^2 = .66$$
$$(6.18) \quad (3.53) \quad (3.12) \qquad N = 50$$

11. Tissue Paper: U.S. to World

$$FR = 102.637 + .015DI - 5.325TV \qquad R^2 = .80$$
$$(15.09) \quad (5.31) \qquad N = 34$$

12. Paperboard: U.S. to Latin America

$$FR = 13.601 + .022DI + .031UV \qquad R^2 = .84$$
$$(22.33) \quad (3.66) \qquad N = 119$$

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LONG RANGE TIMBER DEMAND/SUPPLY PROSPECTS IN JAPAN AND SOME PROBLEMS

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Introduction:

The subject of the transition of the timber demand and supply to the present time is covered in the report by Mr. Yoshio Utsuki, so I shall here discuss the prospects for supply/demand and some problems in the future.

As to the outlook for the future demand and supply in Japan, we have the "Long Range Demand and Supply Projection for Important Forest Products," which is prepared under the provisions of the "Forestry Basic Law" (1964). The most up-to-date version was published in May 1980, due to the change in the economic structure, or the slowed-down economic growth brought about by the oil crisis in October 1973.

The timber demand and supply projection is the only officially recognized projection, so, using this as the base, and supplementing some comments, I should like to present my opinions.

1. Timber Demand

The most recent timber demand projection by the government in May 1980, is as indication in Table 1.

Taking the actual results for 1976, which came to 104.4 million m^3 as 100, the projection for 1986 is 113, at 118.4 million m^3, and for 1996 is 128, at 133.2 million m^3. If we compare the projection prepared in 1973, which in 1981 the level already reached 134.8 million m^3, and forecast for 1991 the volume of 147.3 million m^3, we may say that the 1980 projection was on a considerably low level as compared with the 1973 projection.

How should we look at the recent projection, which is far below the level of the preceding (1973) projection?

The recent projection of timber demand breaks down forest products into five groups, (1) saw timber, (2) pulpwood, (3) plywood, fiberboard, and particleboard, (3) logs which are used for "shiitake" cultivation, and fuelwood, and (5) other uses, and the projection for each of the groups was conducted with the appropriate regression formula.

It may be said, therefore, that in the strict sense, it is more desirable to give the details for each group and to comment on them. A long range projection, however, is projected literally to cover an extremely long range, and, due to this reason, it may not be very meaningful to offer comments on the details. In fact, I feel that comments from the macroscopic viewpoint would point out the problems better and make them clearer. In this sense, I should like to discuss the projection for the total volume of the timber demand.

The results of the recent projection have already been introduced. When they are viewed from the standpoint of the growth rate, using the 1976 results of 104 million m^3 as the base, the annual growth rate until 1986 is approximately 1.3%, and that for until 1996 is approximately 1.2%.

Generally speaking, the timber demand, as in the case of other commodities may be regarded as being largely restricted and affected by the trend of the general economy, and in number, by the national income.

Table 1 Prospects of Timber Demand/Supply in 1973, 1980

(Unit: 1 million m^3)

Report	Demand and Supply	Uses and Sources	Result of 1969-1971	1976	1981	1986	1991	1996	2121
The 1980 projection	Demand	Sawtimber		57.4		62.6		65.4	
		Pulpwood		29.6		36.1		44.9	
		Plywood, Fiber-board, Particle-board		12.8		14.9		17.6	
		Shiitake Cultivation Logs, Fuelwood		2.9		3.6		4.1	
		Other Uses		1.7		1.2		1.2	
		Total		104.4		118.4		133.2	
	Supply	Domestic Supply		38.2		46.2		57.7	
		Imports		66.2		72.2		75.5	
		Total		104.4		118.4		133.2	
	Proportion of Import Percent			63.4		61.0		56.7	
The 1973 projection	Demand	Sawtimber	60.4		71.6				
		Pulpwood	23.5		40.1				
		Plywood	12.3		20.5				
		Other Uses	3.6		2.6				
		Total	99.9		134.8		147.3		152.9
	Supply	Domestic Supply	46.3		49.7		58.7		94.3
		Imports	53.6		85.1		88.6		58.6
		Total	99.9		134.8		147.3		152.9
	Proportion of Import Percent		53.7		63.2		60.1		38.3

In general, the future growth rate of the timber demand may be obtained by multiplying the income elasticity coefficient of demand, the percentage of the timber demand increase rate for the national income increase rate, by the anticipated future increase in the national income.

The recent timber demand projection uses the economic growth rates adopted by the "New Economic Society Seven Year Plan" of 5.5% as the annual growth rate until 1985, 5.0% for 1986 to 1990, and 4.5% for 1991 to 1996.

On this basis, if the timber demand growth rate for 1976–1986 is to result in 1.3%, and for 1986–1996 result in 1.2% on the annual base, what would be the income elasticity coefficient utilized for the projection?

It is assumed that the economic growth rate until 1986 is 5.5%, and, in order that the annual growth rate for the timber demand be 1.3%, it is estimated that the income elasticity coefficient will be approximately 0.24. Then, for the period following, as it is assumed that there will be a 5.0% economic growth rate for the first half, and 4.5% for the second half, we may assume that the economic growth rate for the time until 1996 will average 4.8%. Thus, during this period the income elasticity coefficient of timber demand may be estimated to be approximately 0.25.

The problem now is the 0.24–0.25 income elasticity coefficient of timber demand, which is presumed to be the basis for the timber demand projection.

If we take the total demand volume of 62.6 million m^3 in 1961 as 100, for the timber demand in 1961 to 1973, the time of the high economic growth, the figure increased grandually to 115 in 1965, to 167 in 1970, and 191 in 1973.

During this period, however, the income elasticity coefficient of timber demand showed a gradual downward trend, the opposite of the trend of the absolute value. To comment in terms of approximate numbers, it was about 0.6 during the early stage of the period of high economic growth, becoming 0.5–0.4 during the intermediate stage, and declining to 0.3–0.2 in the last stage.

As a brief explanation of the causes which led to this trend, the following two reasons may be mentioned.

First, the total building construction area, or the number of units, shows a trend of increase, but the share of the wooden construction area, or the percentage of wooden units, shows a trend of gradual decrease.

Second, due to the greater prominence of non-wooden construction materials, such as steel, aluminum and plastics, and their gain of a larger market, the volume of lumber used per unit area in various buildings began to show a decrease.

Due to the reasons stated above, the trend of the income elasticity coefficient of timber demand was that of decrease, and the recent (1980) timber demand projection by the government clearly gives the lowest value experienced during 1961 to 1973.

In other words, a conclusion may be formed that the recent demand projection anticipates a continuing slow economic growth and admits that there will be a declining trend in the construction sector, as has been noted since the past, and the projection may be described as considerably restrained and cautious. Can we assume, however, that there is a guarantee that the timber demand on this level will be realized in the future?

Frankly speaking, there is no guarantee. If the declining trend of the income elasticity coefficient of timber demand until the present is extended and viewed objectively, we cannot but think of adopting an even smaller coefficient.

If so, if the timber demand projection, which is considered as being on an extremely low level, to be precise, in comparison with the increase rate for the timber demand during the period of high economic growth, is to be realized, the pertinent government offices and the timber-related industries should exert constructive efforts for expansion.

What, then, are the prospects for supply to meet the prospects for the foregoing demand?

2. Timber Supply

As to the prospects for timber supply, the data on resources, to be frank, are not reliable, and due to the complicated factors for determining the supply, and their uncertainty (for example, the political instability in the south seas timber supplier countries), it is extremely difficult to present a projection of high accuracy in enumeration data on a level that corresponds with the demand projection. It is anticipated that the various factors of supply must be evaluated from an overall viewpoint to make a forecast based on probabilities.

The recent (1980) government supply projection makes an estimate of domestic and imported timber supply from the following viewpoints.

The details are, first, with regard to the domestic timber supply, it is proposed to unify the age classes of future plantations to the greatest degree, or, in other words, to practice allowable cutting based on sustained yield operation. On the other hand, it is proposed to make the projection a reality by coordinating the estimated demand (already discussed), and the estimated volume of timber imports.

Also, as to the imported timber supply, it is proposed to estimate the future supply by taking into consideration the state of forest resources, the past import record, and the timber export policies of each timber supplying foreign country, to prepare demand forecasts by end use, and coordinating with the forecast for domestic timber supply (Table 2).

When we review the record for 1976, we note that, out of the total timber supply volume of 104 million m^3, domestic timber accounted for approximately 37%, or 38.2 million m^3, and imported timber 63%, or 66.2 million m^3. If the total imported timber supply is taken as 100, the shares for timber import by supply source are 31% for south seas timber, 41% for North American timber, 13% for U.S.S.R. timber, 2% for New Zealand timber, and 13% for the others.

Since then, the volume of imported timber supply has actually increased both relatively and absolutely, and in 1980, the imported timber had an approximately slightly below 70% share, or 74.4 million m^3, of the total timber suply volume.

Now, what are the estimated results for the future?

In 1986, out of the total supply volume of 118.4 million m^3, domestic timber is forecast to have a 39% share, of 46.2 million m^3, and imported timber 61%, of 72.2 million m^3. In 1996, out of the total supply volume of 133.2 million m^3, it is estimated that domestic timber will have a 43% share, of 57.7 million m^3, and imported timber a 57% share, of 75.5 million m^3.

Thus, the recent government projection assumes there will be an increasing trend in the total supply volume, and both domestic and imported timber supply volumes are forecast to increase. As to the shares, it is forecast that the domestic timber supply will increase relatively, based on the increase in forest resources, mainly the post-war plantations.

Should we understand that there is no problem with the government supply projection?

As to the estimate that the south seas timber supply, in the imported timber supply, will gradually decrease in the future, although there may be arguments as to the degree, the projection is considered reasonable, from the viewpoint of the present resources situation.

Table 2 Prospects of Supply in Detail

(unit: 10,000 m^3)

Items		1976 (Result) Saw-timber	1976 Plywood Fiber board particle board	1976 Pulp wood	1976 Shiitake Cultivation log	1976 Fuel wood	1976 Other uses	1976 Total	1986 Saw-timber	1986 Plywood Fiber board particle board	1986 Pulp wood	1986 Shiitake Cultivation log	1986 Fuel wood	1986 Other uses	1986 Total	1996 Saw-timber	1996 Plywood Fiber board particle board	1996 Pulp wood	1996 Shiitake Cultivation log	1996 Fuel wood	1996 Other uses	1996 Total
Domestic supply	Softwood	1,793	1	240			106	2,140	2,537	21	305			81	2,944	3,547	250	735			81	4,613
Domestic supply	Hardwood	345	71	928	184	60	43	1,631	346	100	795	258	60	35	1,594	150	142	351	301	60	35	1,039
Domestic supply	Forest Land Residues			49				49			83				83			115				115
Domestic supply	Total	2,138	72	1,217	184	60	149	3,820	2,883	121	1,183	258	60	116	4,621	3,697	392	1,201	301	60	116	5,767
Imports: South sea timber	Log, Sawtimber, Plywood, Veneer	790	1,189	5				1,984	690	1,190					1,880	550	980					1,530
Imports: South sea timber	Chip			68				68			110				110			200				200
Imports: South sea timber	Sub-total	790	1,189	73				2,052	690	1,190	110				1,990	550	980	200				1,730
Imports: North America timber	Log, Sawtimber, Plywood, Veneer	1,869		4			5	1,878	1,600	60					1,660	1,350	150					1,500
Imports: North America timber	Chip			866				866			900				900			800				800
Imports: North America timber	Sub-total	1,869		870			5	2,744	1,600	60	900				2,560	1,350	150	800				2,300
Imports: USSR timber	Log, Sawtimber, Plywood, Veneer	772	1	35				808	870	30	100				1,000	720	150	350				1,220
Imports: USSR timber	Chip			61				61			110				110			200				200
Imports: USSR timber	Sub-total	772	1	96				869	870	30	210				1,110	720	150	550				1,420
Imports: New Zealand timber	Log, Sawtimber, Plywood, Veneer	118						118	130		70				130	130						130
Imports: New Zealand timber	Chip			34				34							70			70				70
Imports: New Zealand timber	Sub-total	118		34				152	130		70				200	130		70				200
Imports: Others	Log, Sawtimber, Plywood, Veneer	52	18	294		49	15	428	90	90	460		49		689	90	90	550		49		779
Imports: Others	Pulp Products			380				380			678				678			1,121				1,121
Imports: Others	Sub-total	52	18	674		49	15	808	90	90	1,138		49		1,367	90	90	1,671		49		1,900
Imports	Total	3,601	1,208	1,747		49	20	6,625	3,380	1,370	2,428		49		7,227	2,840	1,370	3,291		49		7,550
Total Supply		5,739	1,280	2,964	184	109	169	10,445	6,263	1,491	3,611	258	109	116	11,848	6,537	1,762	4,492	301	109	116	13,317

The problem, however, is that, while a gradually increasing trend is forecast for the U.S.S.R. and New Zealand timber, the opposite, a gradual decrease, is forecast for North American timber.

The figures for 1976 to 1980 clearly indicate that there is an increase of North American timber.

As far as can be seen from the U.S.D.A. Forest Service "The Outlook for Timber in the United States," 1975, and the "Report of the President's Advisory Panel on Timber and the Environment," which takes a critical stand on the former, and as far as can be seen from "An Analysis of the Timber Situation in the United States, published in 1980 as a Draft Review, and the Canadian Forestry service's "Forest Resources and Utilization in Canada to the Year 2000," in 1971, I believe that, in the case of the North American timber imports, although the lumber share may increase and the log import share may show the opposite trend of gradual decrease, there will be no sharp decrease or increase in the share, unless the political interests in the United States take a drastic turn. As to the quantity, however, when the Japanese market trend, which is relatively active when compared with the other countries, is taken into consideration, I do not think there will be any decrease in the future.

This may be a bold statement, but, rather than little fluctuation, I expect a gradual increase, although the degree is not certain.

Furthermore, will the domestic timber supply, which affects the North American timber import outlook, really gradually increase as forecast in the foregoing government projection?

The potential capacity of the domestic timber supply (softwood, to be precise) from the 10 million hectares of man-made forests rapidly expanded after the war, is estimated to reach 60–7.0 million m^3 in the not too distant future, even if we make substantial allowances for unproductive plantations.

On this basis, the already mentioned 46.2 million m^3 in 1986, and 57.7 million m^3 in 1996 are not at all over-optimistic. If this is extended, a share of close to one-half, or even larger for domestic timber at the year 2000 stage is not altogether absurd.

The problem is, however, that in order to achieve prominence in the market, the domestic timber must pass the test of economic competitiveness with imported timber, especially the North American timber, which is a direct rival in the same end uses.

The highly macroscopic comparison of North American forestry and Japanese forestry is treated in my book, "Outlook for North American Forestry," 1977 and T. Kato's "A Regional Comparison of Forest Productivity, Stumpage Prices, Logging and Regeneration Costs among Japan, Canada, and the United States." 1981, but the details may be obtained from them, and I shall here introduce the conclusion.

"Overall" the North American forestry is regarded as much stronger in economic competitiveness.

The basic reasons, with the focus on the Japanese side, may be found in the severity of the natural conditions in the Japanese forests (such as the narrow and steep topographical characteristics), and the very fragmented ownership structure.

Consequently, it is no easy task to overcome such disadvantageous conditions, and more strenuous efforts than ever are required for the improvement of the productivity of the domestic forests, and the systems for manufacturing and distribution. If these goals cannot be reached, and even if the domestic timber has such potential production capacity for the future, it will be difficult to realize an increasing trend in the share of the domestic timber supply as forecast in the recent government projection.

Conclusion:

The foregoing sections were devoted to the introduction of the government's demand and supply prospects for timber, which was revised in May 1980, accompanied by my comments on the future demand and supply situations in Japan.

To be honest, as of the present time, the trends in the general economy, society, and culture, which restrict and affect the timber demand and supply, have changed greatly since 1974, and, moreover, they are extremely fluid in their search for a new order at the present.

Consequently, we must say that the outlook for timber demand and supply in the future requires a continued careful pursuit.

TIMBER PRICE MOVEMENT IN JAPAN SINCE WORLD WAR II AND ITS THEORETICAL CAUSES

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Our Subject:

We should like to discuss the timber price movement in Japan since World War II, or more precisely, from 1960 to the present time, and the theoretical causes.

It is believed appropriate to review the price movement comprehensively, for both the transition and the causes, by breaking down the period roughly into three, which are

I. 1960–1973: Period of high economic growth
II. 1974–1980 (more exactly, April 1980): Period of slow economic growth, early period
III. 1980 (April)–the present time, September 1981.

Present period of slow economic growth, and they will be discussed in their order.

I. Period of High Economic Growth (1960–1973)

During this period a positive policy for bolstering the economy with financial investments and loans resulted in an extremely high economic growth of about 10% on the annual base.

As the effect of such a level of economic activity, or as a part of it, housing starts also were extremely brisk.

Taking the number of new housing starts in 1961, which was 540,000, as 100, the number gradually increased to 129 in 1963, 157 in 1965, 185 in 1967, 251 in 1969, 273 in 1971, and 356 in 1973. During the 13 years from 1961 to 1973 the number increased approximately 3.6-fold.

The timber demand was derived from such brisk building activities, and the demand for timber during this period also showed growth. If we take the 1961 total demand of 61.57 million m^3 as 100, it increased to 110 in 1963, 115 in 1965, 140 in 1967, 155 in 1969, 165 in 1971, and 191 in 1973. The increase for the period was by about 1.9 times. (Table 1)

While the demand for timber showed such an intense growth as described above, the domestic timber supply alone was not sufficient to meet the demand, and timber imports, with relatively large increases in the volume shares of North American and U.S.S.R. timber, showed an extremely noticeable trend of increase.

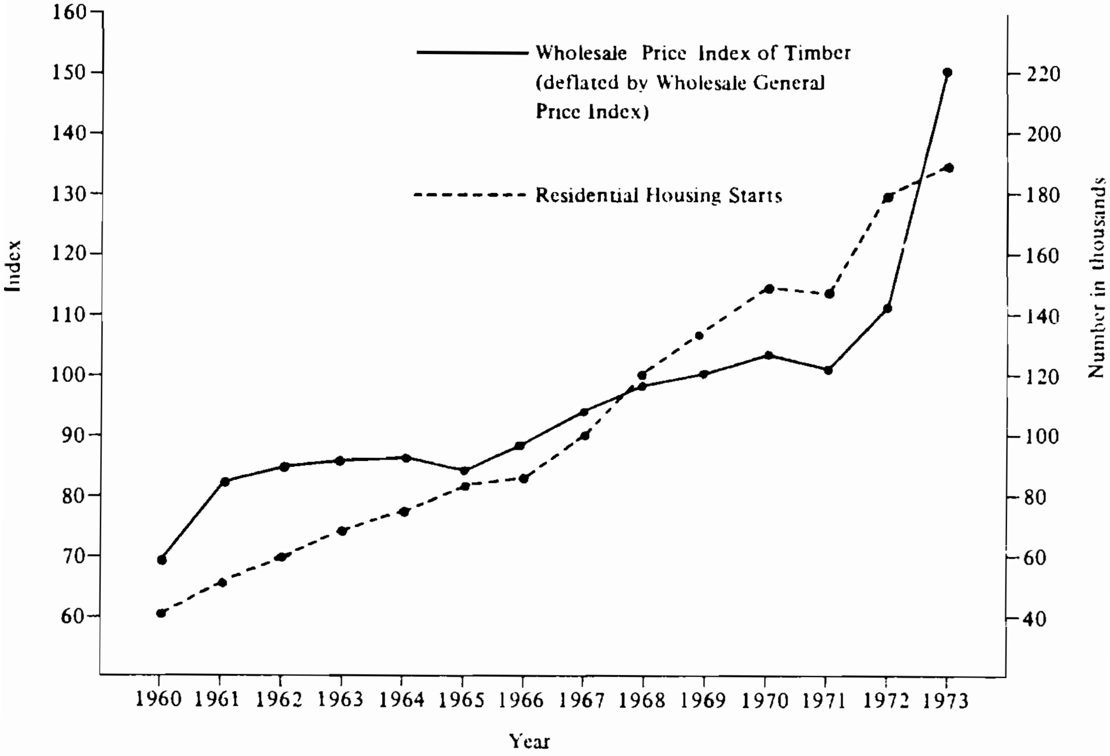
If we review the percentage share of imported timber in the total timber supply volume, we see that it was 18% in 1961, increasing to 25% in 1963, to 29% in 1965, and to 39% in 1967. In 1969 the share was 51%, exceeding one-half, and then, in 1971 it increased to 55%, and in 1973 to 64%.

As to the demand and supply trends for the same period, generally speaking, the increase in

Table 1 Demand and Supply of Industrial Timber in Japan (1,000 m^3)

Year	Demand					Supply										
						Total	Domestic Production			Imports						
	Total	Saw-timber	Plywood	Pulp	Others		Sub total	Logs	Logging-residues	Sub-total	Logs	Saw-timber	Plywood veneer	Chips	Pulp	Others
1960	56,547	37,789	3,178	10,189	5,391	56,547	49,006	48,515	491	7,541	6,674	211			656	
1961	61,565	40,891	3,365	11,834	5,475	61,565	50,816	49,893	923	10,749	9,144	792			813	
1962	63,956	41,964	4,090	12,805	5,097	63,956	50,802	49,807	995	13,154	11,251	897			1,006	
1963	67,761	44,424	4,352	14,615	4,370	67,761	51,119	50,193	926	16,642	13,395	1,254	2	9	1,982	
1964	70,828	46,751	4,943	15,053	4,081	70,828	51,660	50,678	982	19,168	15,692	1,296	10	12	2,158	
1965	70,530	47,084	5,187	14,335	3,924	70,530	50,375	49,534	841	20,155	16,721	1,115	2	270	2,036	11
1970	102,679	62,009	13,059	24,887	2,724	102,679	46,241	45,351	890	56,438	43,281	3,957	548	5,031	3,509	112
1971	101,405	59,801	13,362	25,715	2,527	101,405	45,966	45,253	713	55,439	43,909	2,792	200	5,946	2,472	120
1972	106,504	63,618	14,309	26,202	2,380	106,504	43,941	43,114	827	62,563	47,697	3,222	380	8,076	2,962	226
1973	117,580	67,470	17,151	30,415	2,545	117,581	42,209	41,584	625	75,372	52,485	4,666	1,600	12,094	4,061	466
1974	113,040	60,732	14,481	34,957	2,868	113,040	39,474	38,874	600	73,566	48,453	4,287	882	13,580	5,440	924
1975	96,369	55,341	11,173	27,298	2,557	96,369	34,577	34,155	422	61,792	42,681	2,964	335	11,340	3,688	784
1976	102,609	57,394	12,939	29,639	2,637	102,609	35,760	35,271	489	66,849	45,118	3,821	207	13,025	3,798	880
1977	101,854	56,564	12,717	29,841	2,732	101,854	34,231	33,793	438	67,623	44,561	4,125	118	13,820	4,002	997
1978	103,417	57,560	13,585	29,597	2,675	103,417	32,558	32,145	413	70,859	46,158	4,467	138	13,116	5,954	1,026
1979	109,786	60,314	13,915	32,137	3,420	109,786	33,784	33,270	514	76,002	46,950	5,656	172	15,003	6,413	1,808
1980	108,964	56,713	12,840	35,868	3,543	108,964	34,557	34,051	506	74,407	42,395	6,136	199	15,936	7,670	2,071
1981	103,150	53,650	12,050	34,000	3,450	103,150	32,750	32,300	450	70,400	39,650	5,900	200	15,000	7,650	2,000

Figure 1 Wholesale Price Index of Timber and Residential Housing Starts



the demand was greater than that in the supply. Consequently, the timber price, in comparison with commodity prices in general, showed a much greater rising trend. (See Fig. 1)

The change in the timber demand/supply movement for the same period was more positive and active on the demand side, and, therefore, the factors of the cyclical movement of timber price during the period was, of course, due to both the demand and supply factors, but the demand factor is recognized as more positive and dominant.

Actually, the rising aspect of the cyclical movement during this period coincided perfectly with the peak in December 1961, the so-called "Iwato" boom, the Olympic year boom in 1963, the "Izanagi" boom in July 1970, and the "crazy" price rise period of 1972–1973 and supports the analysis.

Such was the case, but here we introduce a simplified equation for timber price movement, based on the quarterly data for the period, more accurately, from 1965 to 1973. The equation expresses the above understanding in the form of figures.

(a) $PL/PW = -9.08239 + 0.00088531D + 0.31089(PL/PW)_{-1}$
(4.458) (4.602) (2.206)

$-0.179816DMY + 0.6320DMY_1$
(2.151) (3.377)

$+0.27425DMY_2 + 0.16482DMY_3$
(2.304) (1.741)

$R^* = 0.9245$, $S = 0.0797$, $DH = 2.095$

(b) $D = 5950.06 - 115.808\,P/PW + 0.250720BW$
(18.1484) (0.4213) (13.5907)

$-532.044DMY - 289.13DMY_1 - 804.389DMY_2$
(3.2775) (0.2437) (6.9213)

$-777.970DMY_3$
(6.9932)

$R^* = 0.9691$, $S = 250.66$, $DW = 1.414$

Remarks.

PL : Wholesale log price index
P : Wholesale timber price index
PW : General wholesale price index
BW : Wooden construction starts
$(PL/PW)_{-1}$: PL/PW of the former period
DMY : Structural dummy variable (1972, 1973 = 1)
DMY_1, DMY_2, DMY_3 : Seasonal dummy variables
( ) : t value of the estimated parameter
R* : Mulutiple correlation coefficient adjusted degree of freedom
S : Standard error of the estimated equation
DW : Durbin – Watson ratio
DH : D – H ratio of the estimated equation including the lagged independent variable on the right-hand side

$$DH = (1 - 0.5 \times DW) \times \sqrt{\frac{n}{1 - n \times S_1^2}}$$

S_1 : Standard error of the estimated parameter of the lagged independent variable
n : Number of samples

Figure 2 Residential Housing Starts, Hemlock Price and Wholesale Price Index of Timber (deflated by Wholesale General Price Index)

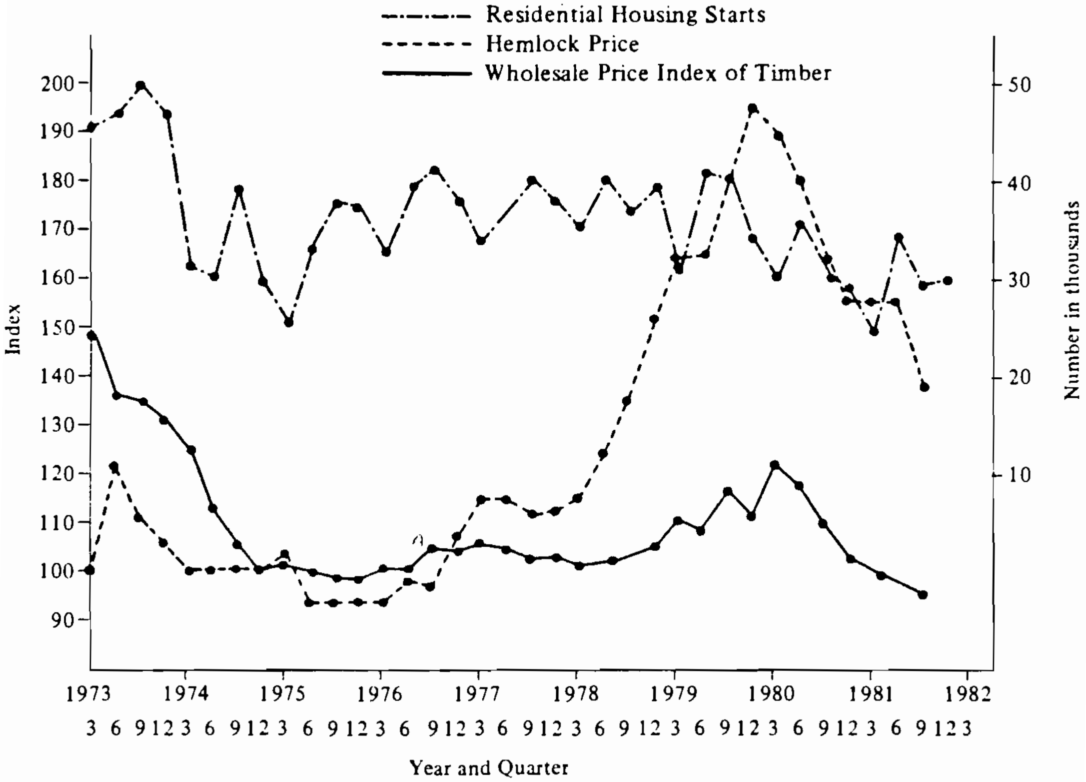


Table 2 Residential Housing Starts

Quarter \ Year	1974	1975	1976	1977	1978	1979	1980	1981
I	317,614	262,808	334,241	340,872	366,571	316,647	307,272	252,505
II	305,084	334,589	389,976	379,019	408,411	415,512	362,600	347,773
III	394,328	384,125	418,410	405,968	377,221	414,461	316,903	297,165
IV	299,074	374,765	381,217	382,401	397,159	349,403	281,851	301,000
Total	1,316,100	1,356,287	1,523,844	1,508,260	1,549,262	1,493,023	1,268,626	1,198,443

Remarks: Numbers of Residential Housing starts for III and IV in 1981 are included estimate.

II. Period of slow Economic Growth — Early Period (1974—April 1980)

As a part of the worldwide economic recession, which occurred with the oil crisis at the end of 1973 as the turning point, the Japanese economy in general reached a time of slow economic growth entirely different from the high growth period. This slowed-down growth has not changed basically to the present time, September 1981.

It is believed necessary to break down this period into two, mainly because of the cause aspect, the first from 1974 to 1980 (more accurately, April 1980, and the second from 1980 to September 1981, for the timber price movement during the slow growth period, in order make projections of price movements in the future.

First, we shall discuss the price movement during the early period of slow economic growth, 1974 to April 1980, and its theoretical reasons.

The price transition for the period is as shown in Fig. 2 and the period may be broken down into the period of no marked fluctuations from 1974 to April 1978, and the period which follows, showing a rising trend.

The theoretical reasons can, of course, be traced to the factors of demand and supply. First, we will look into the demand for timber. Because no monthly or quarterly data of the demand for timber are available, let us study the quarterly trend for the number of new housing starts, the source for our data, (Table 2 and Fig. 2). The 1977 and 1978 housing start levels are not excessively different, compared with the 1979 level, when there was a price rise. In fact, it could be said the 1978 housing start level was much higher than that for 1979.

Then, we must admit that the positive and dominant factors of the price movement were seen on the supply side.

The conclusion on this point is that we may say the import price of North American timber, with a relatively large share of the imported timber, (approximately 30% of the total import volume), and was the most positive and elastic in relation to the timber market, was the determining factor.

The timber price mechanism for this period was as shown in Fig. 3.

The formula for the determination of domestic sawlog price, in the timber price mechanism for this period, is briefly indicated as follows.

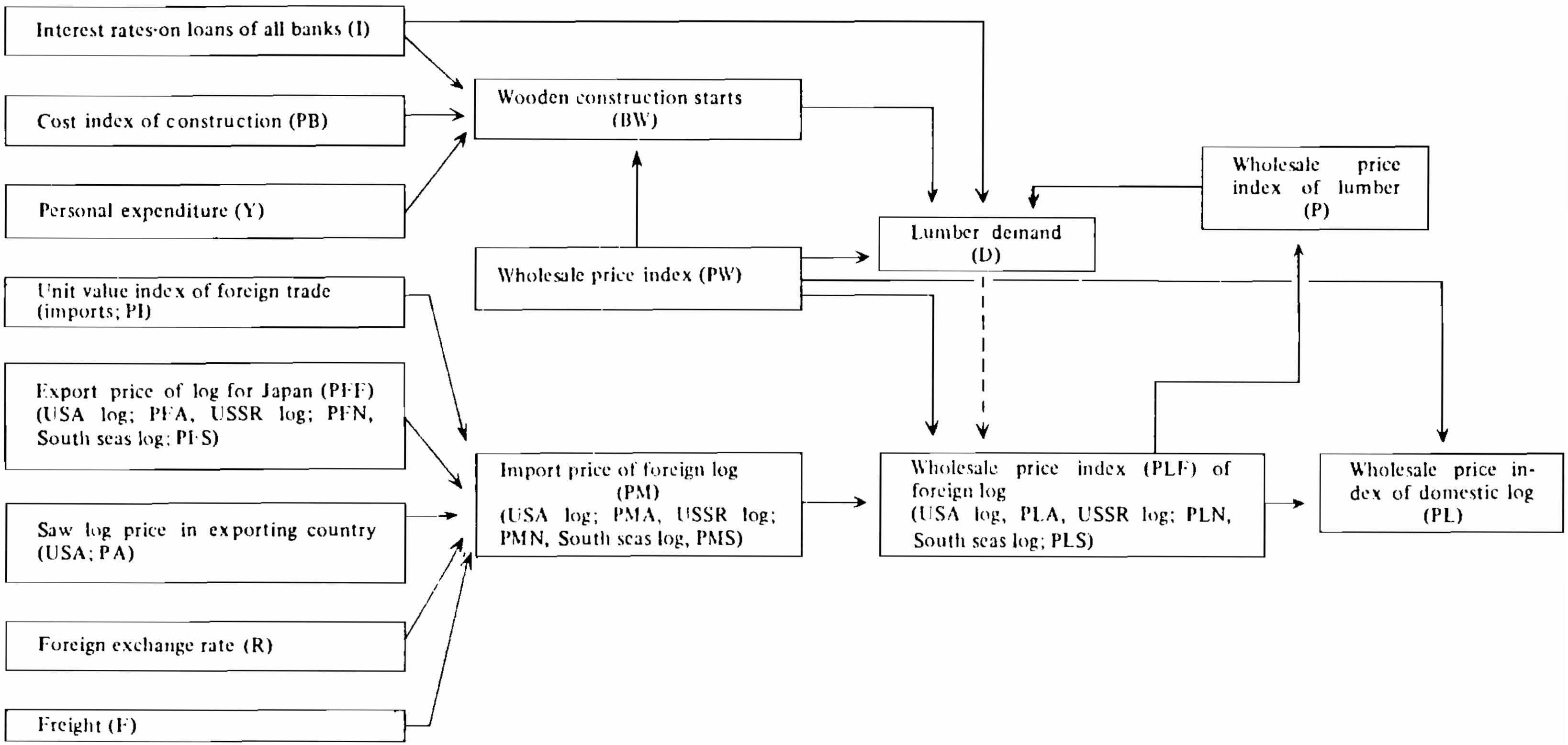
$$PL/PW = \underset{(3.68)}{-0.37041} + \underset{(10.56)}{0.0027081R} + \underset{(18.11)}{0.0010619PFA} + \underset{(2.26)}{0.0043189DMY_1} + \underset{(2.37)}{0.048223DMY_2} + \underset{(3.49)}{0.067272DMY_3}$$

$R^* = 0.96940$ DW = 1.930

Remarks.

PL: Wholesale log price index
PW : General wholesale price index
R : Foreign exchange rate
PFA : Export price of the U.S hemlock log for Japan
DMY_1, DMY_2, DMY_3: Seasonal dummy variables
( ): t value of the estimated parameter
R^* : Multiple correlation coefficient adjusted degree of freedom
DW : Durbin – Watson ratio

Figure 3 Log Price Mechanism in the Period of Low Economic Growth



Remarks: less effect

Table 3 Import price of South Seas Log, North American Log and U.S.S.R. Log

Year	Item / Quarter	South Seas Log Dipterocarpaceae		North American Log Hemlock		U.S.S.R. Log Spruce	
		Price	Index	Price	Index	Price	Index
1973	March	55.0	100.0	285	100.0	46.59	100.0
	June	47.5	86.4	350	122.8	60.24	129.3
	September	51.5	93.6	320	112.3	60.24	129.3
	December	61.5	111.8	305	107.0	60.24	129.3
1974	March	66.5	120.9	290	101.8	68.16	146.3
	June	52.5	95.5	290	101.8	68.16	146.3
	September	33.5	60.9	290	101.8	68.16	146.3
	December	35.5	64.5	290	101.8	68.16	146.3
1975	March	36.5	66.4	270	104.7	55.72	119.6
	June	40.0	72.7	270	94.7	55.72	119.6
	September	39.5	71.8	270	94.7	55.72	119.6
	December	44.0	80.0	270	94.7	55.72	119.6
1976	March	50.3	91.8	270	94.7	48.86	104.9
	June	58.5	106.4	280	98.3	51.10	109.7
	September	66.5	120.9	305	97.0	51.10	109.7
	December	54.0	98.2	335	107.6	61.100	130.9
1977	March	63.5	115.5	330	115.8	63.50	136.3
	June	57.0	103.6	330	115.8	67.50	144.9
	September	57.0	103.6	320	112.3	67.50	144.9
	December	47.5	86.4	320	112.3	63.50	136.3
1978	March	57.5	104.6	330	115.8	60.50	129.9
	June	58.0	105.5	355	124.6	63.50	136.3
	September	62.5	113.6	385	135.1	63.50	136.3
	December	75.0	136.4	435	152.6	79.50	170.6
1979	March	120	218.2	470	164.9	85.30	183.1
	June	150	272.7	470	164.9	94.15	202.1
	September	175	318.2	520	182.5	119.15	255.7
	December	140	234.5	560	196.5	135.19	290.2
1980	March	150	272.7	545	191.2	122.15	262.2
	June	125	227.3	515	180.7	133.15	285.8
	September	105	190.9	475	166.7	122.15	262.2
	December	105	190.9	445	156.1	97.65	109.2
1981	March	110	200.0	445	156.1	100.60	215.9
	June	105	190.9	445	156.1	82.9	177.9
	September	105	190.9	395	138.6	77.9	167.2

Remarks: (1) North American Log price is dollar for 1,000 b.f (SCR)
(2) South Seas Log and U.S.S.R. Log are dollar for one m^3

III. Current Period of Slow Economic Growth (April 1980 to the Present Time, September 1981)

The rising trend of the timber price, which had continued from about September 1979, reached the peak about April 1980, and then started down. There is no sign of recovery as of September 1981.

Let us look at the price transition during the period from the standpoint of the lumber and wood products wholesale price indicator in the Bank of Japan survey. (1975 average = 100). It moved from 159.1 in April 1980, to 153.9 in June, 147.5 in August, 138.9 in October, and 138.4 in December. In February 1981 it was 133.4, in May 132.3, and July 131.1, and then moved on to September.

To what, then, can the cause be attributed?

As already discussed, the possitive and dominant factors of the timber price movement from 1974 to April 1980 was not on the demand side, but the supply side. We traced the cause to the timber import trend, particularly that of the North American timber.

Is the same true of this period?

When we review the transition in the dollar base price of imported logs, as shown on Table 3, south seas, North American, and U.S.S.R. logs all show a large price drop.

When we look at North American logs (Cascade hemlock FAS price), the supply of which was the most positive and elastic for the market, the price in March 1980 per 1,000 b.f. (SCR) was $545, but was $515 in June, $475 in September, $445 in December, $445 in March 1981, $445 in June, and $395 in September, a generally downward trend.

The yen base price, adjusted for exchange rate fluctuation (although not the domestic selling price, believed to reflect it), shows practically the same trend, as can be seen from Table 4.

If so, can we say that the positive and dominant factor for the timber price movement was as in the preceding period, on the supply side, or plainly speaking, the timber import price?

Table 4 Imported-Timber Price Amended by Exchange Rate

Year and Month		Exchange Rate		South Seas Log		North American Log		U.S.S.R. Log	
1977	March	¥280.57	100.0	¥115.5	115.5	¥115.8	115.8	¥136.3	136.3
	June	272.98	97.3	103.6	100.8	115.8	112.7	144.9	141.0
	September	267.04	95.2	103.6	98.6	112.3	106.9	144.9	137.9
	December	241.30	86.0	86.4	74.3	112.3	96.6	136.3	117.2
1978	March	231.51	82.5	104.6	86.3	115.8	95.5	129.9	107.2
	June	214.34	76.4	105.5	80.6	124.6	95.2	136.3	104.1
	September	190.16	67.8	113.6	77.0	135.1	91.6	136.3	92.4
	December	196.24	69.9	136.4	95.3	152.6	106.7	170.6	119.2
1979	March	206.10	73.5	218.2	160.4	164.9	121.2	183.1	134.6
	June	218.89	78.0	272.7	212.7	164.9	128.6	202.1	157.6
	September	222.26	79.2	318.2	252.0	182.5	144.5	255.7	202.5
	December	240.62	85.8	234.5	201.2	196.5	168.6	290.2	249.0
1980	March	248.62	88.6	272.7	241.6	191.2	169.4	262.2	232.3
	June	218.05	77.7	227.3	176.6	180.7	140.4	285.8	222.1
	September	214.85	76.6	190.9	146.2	166.7	127.7	262.2	200.8
	December	209.78	74.8	190.9	142.8	156.1	116.8	209.6	156.8
1981	March	204.19	72.8	200.0	145.7	156.1	113.6	215.9	157.2
	June	217.92	77.7	190.9	148.3	156.1	121.3	177.9	138.2
	September	235.92	84.1	190.9	160.5	138.6	116.6	167.2	140.6
	December								

Remarks: Each imported-log price is based on the March 1973 price = 100

The conclusion is that the answer is "No". We may assume that the demand side factor also had a positive and dominant effect during this period.

This is the opinion gained when we review the trend in the number of housing starts, the main source of the timber demand.

From 1980 the gradual decrease in new housing starts became highly conspicuous and also severe.

The figures are given (in Table 2.) The first half of 1980 (January-June) number of housing starts, as compared with the same term the preceding year, was 92%, or 669,000, and the second half 78%, or 599,000, totalling 1.268 million. The gradual decrease did not stop after the beginning of 1981. The number for the first half was 600,000 units (90% of the same term the preceding year), and the second half 598,000 (figures for August and thereafter are estimates), coming to the total of 1.198 million (99.9% of the preceding year), the lowest level since 1974.

To summarize the foregoing, from the time of slow economic growth to the present, the timber import trend, particularly that for North America, was considered the dominant factor, but after April 1980, the effect of the slowed-down economic growth became even more intense, and resulted in further affecting the timber price decline.

In other words, we may regard it that the serious trend of the demand/supply of timber during the period of slow economic growth has become more prominent after 1980.

Conclusion:

We have discussed the changes in the timber price movement and the theoretical causes for the three periods, which are the period of high economic growth, the early period of the slow economic growth, and the following period to the present time.

Frankly speaking, when we review the principal changes in the Japanese economy since 1973, (1) the changes in the conditions for the import of resources, and (2) the intensifying friction in the internationl market between Japan and the other nations, it is difficult to anticipate renewed high economic growth of approximately 10% on the annual base in the future.

If so, when we seek to project the future movement of the timber price, and the volumes of demand and supply, we believe that it is important to place emphasis on the mechanism for determining the timber price during the period of slow economic growth.

And, we wish to again mention the special features. As can be understood from the fact that the imported timber accounts for approximately 70% of the total timber supply in Japan, the timber price movement and the demand and supply trends, are importantly affected by imported timber, and, in particular, by the condition of the import of North American, which responds the most positively and elastically to economic changes. Second, as the slowdown in the economic growth continued, a downward trend was noted in housing starts, which brought on a gradually declining trend in the demand for timber, and this trend is having an effect on the timber price decline.

It is our plan for the future, bearing these facts in mind, to prepare a forest sector model for Japan that incorporates the various relationships between demand and supply, and the various factors.

ARE WE HEADING TOWARDS MORE REALISTIC MODELS OF DEMAND AND TRADE IN FOREST PRODUCTS?--DISCUSSION

Part I: Comments by Benjamin Slatin[1]

The answer to the above question is "yes, but." The papers presented in this meeting modeling the forest products industry with emphasis on international trade are extremely impressive. Many of them are "state of the art" in terms of current knowledge of econometrics and economic models. Many, however, are in the earlier stages of planning and some are extremely ambitious in their potential scope.

At the same time, it must be recognized that a model by itself, no matter how complicated or sophisticated, cannot predict the future with accuracy. The reason is that models tend to represent the market on the basis of the current structure of the industry in terms of both domestic and international trade potentials. A good model will permit one to make specific assumptions about the inputs in the future and given the identified relationships, foretell the future. The important point is that the model's output is at best a reflection of the quality of its inputs. This is true of both the supply and demand models; in both instances, the forecaster must consider changing situations in the future that are not inherent in the structure of the models themselves.

I can describe this best by discussing the pulp, paper, and paperboard demand models, inasmuch as I spend most of my time studying these industries. In this conference we have heard papers describing the modeling of the forest products industry in general, and the pulp and paper industry in particular, and never once have we heard about electronic storage, transfer and retrieval of information, office copiers or plastics. Yet, developments in these fields have been, and will continue to be, major determinants of the future demand for wood pulp, paper, and paperboard, not only in the United States but also around the world. We have heard some mention of electronic transfer of information, but largely in passing, as a topic that should be investigated. None of the models, to the best of my knowledge, included specific trends or relationships analyzing the potential impact of electronics, office copiers, or plastics on the demand for paper and paperboard. I do not believe that a realistic appraisal of the future can be made without specific assumptions about the impact of these forces on the demand for paper and paperboard.

The Economics Department of the American Paper Institute has been studying these problems intensively during the past year. We have collected a small library of studies that have been made on the impact of electronics and office copiers on the demand for paper and the potential changes in the future. Various organizations, including Federal government agencies and private research companies, have spent millions of dollars on these studies. Yet even with that, the conclusions about future trends are at best tentative and are not always consistent from study to study. The American Paper Institute has

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[1]American Paper Institute, New York.

published one report summarizing this rather extensive bibliography. In addition, the Institute has been studying the impact of plastics on the paper industry and has also published several reports describing trends in this area.

There is one further point I would like to make about these models. Most of them use some indicator (e.g., gross national product, gross domestic production) as a major variable in analyzing the demand for wood pulp, paper, and paperboard. This is a perfectly good way of analyzing demand, but it can lead to misleading results in the future if it is not properly supplemented by additional information. The past supply/demand relationships developed in these terms could change considerably in the future.

Let me demonstrate this point with United States data. The relationship between the demand for paper and paperboard in the U.S. and total economic activity as measured by the real Gross National Product can be analysed in terms of the trend of the ratios of total paper and paperboard new supply (production plus imports less exports) to the real Gross National Product. In 1947, the ratio of new supply to real GNP was 52,000 tons per billion dollars; the ratio also averaged 52,000 tons per billion dollars in 1972 and 1973. Furthermore, year-to-year variations from that trend over that entire 28-year period were fairly small: the lowest ratio was 47,600 tons per billion dollars in 1950. From 1959 to 1974 the ratios fluctuated in the 50,900-53,200 tons per billion dollar range. This is indeed a stable relationship for a single industry relative to total economic activity.

At the same time, this relationship was the sum of widely divergent trends among the various sectors. For example, new supply of printing/writing papers in 1959 was equivalent to 9,509 tons per billion dollars of real GNP; in 1974 this reached 10,917 tons. In that same period, staying with the growth sectors of the industry, unbleached kraft paperboard rose from 6,792 tons per billion dollars of real GNP to 9,423. The other part of containerboard, semichemcial paperboard, went from 2,429 tons to 3,228 tons per billion dollars of real GNP. In that same period, the ratio of new supply of packaging and industrial converting papers to real GNP declined from 5,574 tons per billion dollars to 4,553 tons, while the recycled paperboard ratio fell from 9,652 tons to 6,055 tons. These divergent trends show that the relative stability in the relationship between total paper and board demand and total economic activity was the fortuitous result of widely divergent trends within the various sectors of the paper and board market. Simple extrapolation of the average relationship into the future, without taking into account the specific market trends and the reasons for these trends, can lead to serious miscalculations in estimating the future.

This same analysis shows not only the need for a more detailed structure of the industry than relationships based on a demand indicator (and price) alone, but also the importance of including in the model itself factors describing the impact of competitive materials or processes that affect the demand for each of the major grades of paper and paperboard. Without this information the models can only project mirror images of the past.

Part II: Comments by Dale Kalbfleisch[1]

I have two observations about the question: "Are we heading towards more realistic models of demand and trade in forest products?" The first is that, from my perspective, modeling domestic product demand is still more advanced, relatively, than modeling either supply (especially raw material supply) or trade. The demand models tend to be specified more completely, and the structures more realistically capture real world determinants and decision processes. This does not mean that there are no uncertainties or that the forecasts are necessarily good; only that, in the relative sense, we know how to model demand.

Supply modeling, especially raw material supply, is considerably less advanced. A great deal of attention is now being given to raw material supply modeling, however, so some catch-up in the state-of-the-art seems likely on the supply side.

But, trade remains not well defined in most models. Trade is usually exogenous in the one-country models, although David Darr has described to us the beginnings of how the Assessment process will incorporate some price sensitivity to U.S. trade flows. In world supply-demand studies, trade is usually developed through a balance-the-gaps approach. In these formulations, trade is not price responsive. As a result, the impacts of alternative policies and the characterizations of uncertainty of key variables cannot be determined. This seems to me a serious weakness. How can we expect credible results if demand and supply changes, resulting either from policy actions or as a measure of uncertainty, cannot flow through realistically to changes of imports or exports?

This prompts my second observation: support of IIASA's world forest sector project appears to be an efficient way to begin to improve our understanding of trade modeling. The IIASA project is designed to deal specifically with trade--trade is designed in from the beginning in the way that, as economists, we should think of trade flows as being determined. That is, demand for one country's exports will be a derived function of both demand and supply conditions in other countries.

It seems to me that acceptable modeling results--whether from a desire to understand private investment opportunities of national public policy choices--require us to integrate models across geographies in a structured way, which recognizes that trade flows are determined by competitiveness in international markets. The IIASA project should be able to help do this.

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FOREST SECTOR MODELS

Edited by Risto Seppala, IIASA, Clark Row, USDA Forest Service, and Anne Morgan, IIASA

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Forestry and the forest industry are facing major structural changes. On the production side, the development of processing technology has made the industrial use of wood commercially possible in many new areas; at the same time, wood growing has reached its economic and institutional limits in some old forest areas. As a consequence, a major shift in the global pattern of the supply of wood raw material is taking place.

Over the long term, the consumption pattern of forest products is changing: for traditional products, some countries are reaching saturation level whilst in others a considerable increase in demand is anticipated, and technological innovations are changing the overall demand for different products.

These issues pose problems that require a global analysis.

Forest Sector Models, based on the First North American Conference, includes many impressive state-of-the-art papers in terms of current knowledge and econometric models. It covers modelling the forest products industry with emphasis on international trade, and represents an important step in improving the ability to model forest management investment. **Part I** introduces the Forest Sector Project of the International Institute for Applied Systems Analysis; **Part II** presents approaches to developing forest sector models; **Part III** emphasises some of the sub-problems in model development, specifically on the development of realistic long-term supply response estimation capabilities; **Part IV** covers approaches to modelling demand and international trade components.

Forest Sector Models reflects the initiative and aims of the IIASA forest sector project, which includes two interacting tasks: national forest sector analysis, and analysis of world trade in forest products.

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