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Forestry Sector Analysis for Developing Countries: Issues and Methods

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Abstract

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A satellite meeting of the 10th Forestry World Congress focused on the methods used for forest sector analysis and their applications in both developed and developing countries. The results of that meeting are summarized, and a general approach for forest sector modeling is proposed. The approach includes models derived from the existing literature and can be used as a structure for applying forest sector analysis in developing countries.

Keywords' Supply-demand relations, forest sector modeling, developing countries (forestry), Third World.

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Introduction

A satellite meeting of the 10th Forestry World Congress (held in Paris, France, September 1991) focused on the methods used for forest sector analysis and their applications in both developed and developing countries. This meeting was motivated by the growing recognition among government and nongovernment organizations of the need for more systematic and complete analysis of the forest sector. Where once viewed in extremely local terms, long-term forest land stewardship and economic development issues increasingly involve entire national forest sectors. Proposed changes in one aspect of the forest sector, such as a new processing facility or changes in land management or tenure practices, have effects that ripple through the entire forest sector and may impact other economic sectors. (By forest sector, we mean the consideration of all aspects of forestry from the basic land tenure issues, to harvesting, production, and consumption decisions. Such a view is no different than similar views of various agricultural and industrial sectors in an economy.) Often the indirect impacts are the most enduring, outlasting the immediate and direct impacts of a specific project.

Much of the impetus for this work comes from observing the disparity of forest analysis and planning methods and applications among countries. Countries in North America and Europe have made much progress in analyzing and managing their forest resources, but countries elsewhere have neither benefitted from these analytical advances nor advanced very far in understanding their forest sectors. Until recently, forest sector analysis in the developing world rarely has involved applying a model, and this usually has been limited to an inventory exercise. There is need for improvement, however, as international concern for forest resources is rising, and expanding populations and growing economies are increasing the demand on the natural resource base. For these reasons, government and nongovernment agencies are directing their attention to applying forest sector models to developing countries.

This change in attention will show how the forest sector in developing countries differs from that in developed countries. Principle differences are the size and structure of the macroeconomy within which the forest sector exists. For forestry and especially forest management, the agriculture sector and the nature of agriculture production are especially important. Unlike developed countries, agricultural production occupies the majority of the rapidly growing population in the Third World. Because opportunities are limited for yield increases through intensive management, demand for agricultural production often is satisfied with extensive cultivation of marginal areas, especially in the tropics. This results in conversion of forest land to agricultural production. Demand for fuelwood, poorly defined property rights, and extreme poverty combine to put further pressure on forests, and natural resource degradation usually is the result.

A complicating factor in forest sector analysis in developing countries is the lack of data. This seriously limits applying some of the more complex models at the same time that demand for comprehensive analyses of the forest sector is rising. In developed and developing countries, increasing recognition of tropical forests as both economic and ecological resources is amplifying calls for greater recognition

¹ The proceedings from the 10th Forestry World Congress (Haynes and others 1992) included an array of efforts tracing the development and application of a broad range of forest sector models for both developed and developing countries and dealing with a wide range of issues

of nontimber products and ecological services. To be widely applicable in the developing world, forest sector models must be able to tackle these complex issues while accommodating constraints presented by scarce data and limited resources.

In this paper, I first summarize the results from the September 1991 conference (Haynes and others 1992) and propose a general approach for forest sector modeling. The general models that I propose are derived from the existing literature (most of it summarized in the various papers presented at the World Forestry Congress) and can be used as a structure for applying forest sector analysis in developing countries. It is important to remember that informal forest sector analysis methods have long been part of the tools available to foresters. In the next section, I've traced the evolution of forest sector models and used the experience of the United States as an example. In the third section, I've proposed two broad classifications for forest sector models and illustrated how they can be applied in various situations.

Evolution of Forest Sector Models

Evolution of Model Form

This section describes the evolution of the form and use of forest sector models. For the use of the models, I am concerned with changes both in how models are used in policy analysis and their applicability to issues in developing countries.

The theoretical and methodological roots of forest sector models evolved from basic economic issues explored in the 1950s and early 1960s by Samuelson (1952), Tramel and Seale (1959), Takayama and Judge (1964, 1970), and later by McCarl and Spreen (1980). The term "forest sector" first was used by Panders and others (1978) to describe their model of Scandinavian forestry. In the early 1980s, the term "forest sector model" came into general use largely through the Forest Sector Project at the International Institute for Applied Systems Analysis (IIASA). This project developed a global trade for model forest products (Kallio and others 1987). The IIASA project stimulated research in a number of countries and generally popularized the version of forest sector modeling, pioneered in the United States by Adams and Haynes (1980), that relied heavily on economic representations and market solution algorithms.

Forest sector models² are characterized by a systems view of the biological and social processes in forestry. The importance of this systems view is that it can be used to explore the biological development of forest resources and the attendant dynamics of the forest industry over time and under alternative futures and management strategies. A basic premise is that various relations describing (or mimicking) biological and social (predominantly economic) processes can be specified.

These models have been used to organize various views of the forest sector and to derive useful information for improving and expanding the perceptions held by land managers, the public, and government and nongovernment agencies. In some countries, such as the United States, forest sector models have been used to assess present and future resource conditions, demands for forest products, and in the last several decades, prospective price trends. In this role, models have helped guide land stewardship decisions.

² The use of the term "model" here means the development of abstract representations. It takes on a semimathematical definition only when the discussion turns to model specification and solution.

In the evolution of forest sector models in the United States, for example, the earliest of the assessments³ focused almost exclusively on resource conditions and were used to argue for conservation and management of timberland resources. There was little analytical framework in these early studies, as most were descriptive discussions of subjectively drawn trends in resource conditions and use. After World War II, harvest levels in the United States began to increase, thereby stimulating and requiring more detailed planning frameworks. More recent assessments have depended on analytical frameworks incorporating supply-demand representations; price and quantity determination in both stumpage⁴ and product markets; and projection of timber inventories by region, owner, and timber type.

The evolution of forest sector models from simple Malthusian concepts of catastrophic scarcity to integrated planning models was guided by (and responding to) a changing policy context. Early policy context argued for conservation and wise use of renewable resources. Currently, a shift is occurring in various national and international economic policies away from the progressive vision⁵ of government objectively pursuing the public interest⁶ to a vision of government economic policies driven by continual competition among interest groups. This competition has increased since the mid-1980s, evolving from competition among commodity-oriented interest groups to competition among commodity, noncommodity, and environmental groups at both local and national levels. Forest policy goals derived from the progressive movement were to reform forest practices and make them serve the public interest. Modern forest policy goals involve sustaining the flows of goods and services from forest lands that meets national (and local) needs. Each policy goal requires a different analytical paradigm.

³ Analysis of the demand-supply situation for timber has a history in the United States dating to 1876. The complete bibliography of these assessments is given in appendix C of Haynes (1990).

⁴ "Stumpage market" is a term used for those wood markets where the timber is sold by standing volumes. In such markets, the purchasers bear the cost (and associated risks) of harvesting the wood. An alternative form used in some areas of Europe is a log market where timber is sold after harvest but before removal from the forest. A third variation, used in parts of Canada, is a market based on delivered wood costs. These are just different ways of pricing a factor of production.

⁵ The progressive movement, at the end of the 19th century in the United States, sought to introduce scientific methods and techniques to the solution of public issues.

⁶ One common manifestation of the public interest has been the intent of many natural resource management actions to contribute "to the greatest good for the greatest number." Nelson (1987) describes this shift in government economic policies for the United States.

The experience of the United States illustrates how the changing policy context influenced the development of forest sector models. The experience also illustrates how methodological developments contributed to and facilitated the evolution of forest sector models. The experience in the United States also owes much to the development of spatial equilibrium commodity models used in the agriculture sector. The attributes of these latter models are described by Bawden (1966) who also describes their potential applications to international trade questions. Agricultural commodity models in the United States include supply and demand representations, spatial treatment of production and consumption, factor and product market distinctions, and in some cases, well-defined policy variables. Their evolution and especially their use of spatial market mechanisms are described by Thompson (1981).

The chief advocate for forest sector models in the United States has been the USDA Forest Service. The Forest Service is the government agency responsible for managing the National Forest System, which has evolved in the 20th century to include 77.2 million hectares of forest and grass lands accounting for roughly one-fourth of all U.S. forests. Starting in the 1960s, the Forest Service began developing formal planning frameworks. The basic approach was a trend analysis of demands for forest products and availability of timber resources (USDA Forest Service 1965, 1974, 1982). Policies and emerging trends were discussed in the context of the gap between the trajectories of the demands for forest products (expressed as roundwood equivalents) and the prospective availability of timber. In time, this approach became known as a gap analysis (or the gap model) and was applied in the United States as the primary forest sector model until the late 1970s. During the 1960s and 1970s when it was commonly used, gap analysis evolved to include price trends.

Much of the evolution of forest sector models beyond gap models was stimulated by changes in policy issues away from describing policy needs by quantity shortfalls (that were never observable with real world data) to identifying policy needs by price impacts. This shift in the United States occurred in the mid-1970s during a period of rapid changes in commodity prices and concern about the effectiveness of various policies to alter selected price trajectories. The implication of this shift for model builders was that future models needed to be built around supply and demand representations directly including price as an independent variable and that model-solution processes needed to seek the price and quantity equilibrium. This class of model has become known as equilibrium models.

Starting in 1977, the Forest Service undertook the development of a forest sector model designed to explicitly explain regional stumpage price behavior. This model was built around a spatial equilibrium algorithm.⁷ The initial purpose was to develop

⁷ The emphasis on regional markets meant that the model had to deal with the spatial juxtaposition of stumpage markets. Samuelson (1952) generally is credited with defining the problem, but its solution until the last decade has always involved complex computational methods. Previous experience with linear programming models both in agriculture and forestry led model builders in the United States to select a computationally simpler algorithm (a reactive programming algorithm developed by King and Ho [1972]) to solve for spatial equilibrium.

regional harvest and price trends as required by the Resources Planning Act (RPA).^p The resulting model called TAMM (described in a later section) exceeded all expectations (Adams and Haynes 1980, Haynes and Adams 1985). It produced regional price trends in both product and factor (stumpage) markets that recognized simultaneous market interactions and differences in regional timber resources. This model built on early econometric studies (such as those by Adams 1974, McKillop 1967, Mills and Manthy 1974, and Robinson 1974) and linear programming efforts that attempted to solve spatial market concerns (for example, Haynes and others 1978, Holley 1970, Holley and others 1975.)

The use of forest sector models continues to evolve in the United States and elsewhere. This evolution is guided by advances in our understanding of market mechanisms (behavioral models of production, consumption, and capacity adjustment), solution algorithms, timber inventory projection systems, and the role of forest sector models in policy formulation. Research on forest sector models can require a long-term commitment. In Sweden, for example, a 7-year project to develop a model of the forest sector is just beginning to produce results (Lonner 1991). This Swedish work generally follows the basic economic theory in that it seeks long-term equilibria between demand and supply both in the forest industry product market and in the wood raw material market.

Model Taxonomy

During the past two decades, several types of forest sector models have evolved. The two most popular are the gap and equilibrium models, which include a wide array of contemporary models that have been applied to various forest sector problems and issues. The primary distinguishing feature is the role of prices.

It should not be assumed that one class of model is necessarily better than another. Even though equilibrium models evolved, in part, from the inability of gap models to address specific policy questions, both classes of models appeal to different audiences of policy makers. The gap model has much intuitive appeal because policy-makers can gauge the amount of timber needed as the goal of a policy action (this assumes that the most common policy action would be "to fill the gap"). The equilibrium model appeals to policy makers interested in price changes and estimates of consumer or producer impacts. Within the Forest Service, all policy discussions in the last decade have been based on the equilibrium models, but decisionmakers still find it useful, at times, to frame a policy discussion around the notion of some quantity (that is, the level of the timber sale program) associated with a particular issue.

^p The Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974 as amended by the National Forest Management Act of 1976 directs the Secretary of Agriculture to prepare a renewable resource assessment. The purpose of this assessment is to analyze the timber resource situation to provide indications of the future cost and availability of timber products to meet the Nation's demands. The analysis also identifies developing resource situations that may be judged desirable to change, and it identifies developing opportunities that may stimulate both private and public investments.

Some Examples of Forest Sector Models

Both model types are based on discrete time intervals. A third type of model is based on continuous time relations. Such models use system-dynamics principles (Forrester 1961). One such model is the SOS model of the Scandinavian forest sector (Panders and others 1978). This model viewed the Scandinavian forest sector as a set of cause and effect relations. Another model is the TSM model developed by Sedjo and Lyon (1990) and applied to international forest resource questions. These models have had only a limited impact on the design of forest sector models. The majority of forest sector models have been derived from various economic models and consequently have shared the economists view of market processes.

In this section, I review some example modeling efforts that illustrate some of the points made above. These examples include descriptive types of approaches and gap and equilibrium types of models,

Descriptive studies—Beyond the relatively narrow modeling literature, there is a rich body of studies dealing with forest sector issues descriptively. Many of these studies have been done by government and nongovernment organizations, in some cases as part of various developmental assistance efforts. For example, the Food and Agriculture Organization (FAO) of the United Nations, demonstrates at least two approaches in its analytical efforts: the first is illustrated by studies reporting on country projects that have planning or policy content; the second approach is illustrated by projects undertaken as part of the tropical forestry action program (TFAP).

The FAO has about 300 currently active forestry projects;⁹ about 10 percent are concerned mainly with forest development planning and about 2 percent with supply analysis. Many more, however, may have a policy or planning component and involve various types of modeling inputs. Some projects have a significant quantitative planning content. A number of FAO references are documented by the FAO (1991). There are two general types of FAO documents. First, there are a number of publications dealing with the collection and dissemination of statistics; examples are the *Yearbook of Forest Product Statistics*, *Forest Product Prices*, and periodic outlook studies. The second group of publications describes the outlook for various national forest sectors. The objective of the latter studies is to provide an international capability to prepare perspectives on future development of the forest sector as a framework for policy formation and decisionmaking as required by national governments and nongovernment organizations. This perspective addresses such issues as:

1. Development of the demand for forest products.
2. Supply potential of forests, including consideration of competition for land resources, and the supply potential of forest industry.
3. Development of trade.

⁹ Wardle, Phillip. Correspondence dated 5 March 1992
Senior Forestry Economist, FAO

4. Implications for investment in forestry and industry.
5. Implications for rural communities, people, and employment.
6. Implications for the environment.

The broad concept behind the FAO forest sector studies is similar to the economic theory-based approaches used elsewhere. Such studies deal with estimating demand and supply of forest products and wood raw materials through an analysis of historic relations among consumption, production, and economic indicators. To the extent possible, an equilibrium is sought between demand and supply. Finally, such studies try to assess the implications of the development path for major variables under given policy issues of interest.

The experience of the European timber trends and prospects studies—Since 1952, a series of studies on the outlook for the forest and forest products sector in Europe has been prepared and published under the auspices of two intergovernmental bodies: the Timber Committee of the United Nations, Economic Commission for Europe (UN/ECE), and the FAO European Forestry Commission (United Nations 1953, 1964, 1976, 1986). Preparations are in hand for the fifth of these studies, known collectively as the European timber trends studies (ETTS), to be published in the mid-1990s.

The ETTS studies have analyzed the outlook for supply of and demand for forest products and the balance between the two. They are intended for use primarily by national governments in policymaking for the forest sector, but they also have been found useful by academic researchers and by private trade and industry analysts. The various ETTS studies are among some of the best contemporary examples of gap types of forest sector models.

From ETTS I to ETTS IV—The situation facing the authors of ETTS I in the early 1950s was truly challenging: a climate of uncertainty existed over general trends of the economy as a whole, and there were significant political problems (start of the cold war). Problems facing analysts of the forest sector included comparable uncertainty about the future and a weak database; only four countries had a forest inventory more recent than the early 1930s.

Egon Glesinger, the first director of the ECE/FAO Timber Division, led a dynamic team that was able (with modest resources) to assemble a database and mobilize sufficient expert knowledge of forest resources, forest products markets, and end uses of products. The outlook period was to 1960; although most of the work was carried out by the core team, they had access to national data and expertise. This group reached the conclusion that demand for forest products in Europe would expand strongly in the 1950s; it was argued that both supplies from the USSR and a "dynamic forest policy" for Europe were necessary to satisfy the expected demand. In spite of how reasonable they may seem to us now, these conclusions and recommendations were controversial at the time.

All the ETTS studies, from ETTS I to ETTS IV, have been built on the same basic structure. They begin with separate analyses of the outlook for demand for forest products and of the likely supply of timber from European forests. Forecasts of demand for products are converted to raw material requirements (also called raw material equivalents), thereby taking into account production efficiency. A comparison of the supply and demand balance for individual countries also takes into account, to the extent possible, factors such as international trade and recycling. The ETTS studies always have been complete in their coverage of European countries and of all timber-based products. Although each study has drawn policy conclusions, these conclusions have not been particularly specific or controversial since ETTS I. The value of the ETTS studies has been seen by participants and users alike as providing a broad analytical framework and a compilation of data, within which individual countries or industries could address their own specific problems.

Over the years, the ETTS database has improved significantly, thanks in part to the efforts of the body now known as the Joint FAO/ECE Working Party on Forest Economics and Statistics. Time series data describing timber harvest and production and trade in forest products have increased in quality and length. Forest resource data are more consistent and comparable across countries. Improved data have not led to significant changes in the basic methodological approach, however. Beyond the use of econometric methods for demand analysis, the basic gap framework remains much the same. The changes in the methods used for demand forecasts, starting in the fourth ETTS study (United Nations 1986), were the result of efforts to achieve consistency with those done by the FAO (1988).

The broad structure of ETTS IV (United Nations 1986) had the following elements:

- Quantitative forecasts to 2020, by country, for European forest area, growing stock, growth, and removals from forests, based on data from national correspondents.

- Econometric projections of consumption of products, by country, with presentation and analysis of recent trends in end uses and prices.

- A description of the situation of the European forest industries in the mid-1980s, with estimates of future trends in recycling of waste paper and the use of residues in manufacturing.

- A description of trends in interregional trade and an analysis of the capacity of exporting regions to expand their supply to Europe.

- Quantitative forecasts of wood used for energy, developed from a survey of national correspondents.

These elements are combined in an analytical framework comparing physical forecasts of roundwood supply and forest products demand, after making specific assumptions about recycling, trade, and conversion efficiencies (in production). The result is a set of "gaps" that simply indicate that some or all of the fixed assumptions underlying the forecasts are unlikely to be realized. These prospective gaps (that will never actually materialize, because markets adjust continuously) may trigger adjustments in policies or in the decisions of producers or consumers. Unfortunately, this section was widely misunderstood, with many seeing the gaps as forecasts.

One of the few serious criticisms of ETTS IV was that internal consistency in economic terms was lacking because there was no analysis of industrial supply comparable to the analysis of consumption. Although price is an explicit component of consumption forecasts, it is not an element of roundwood supply forecasts. In addition, the response of producers (those buying roundwood and selling the products consumed) is not considered in the analysis. To address this problem, efforts are underway to develop product supply forecasts that will establish a basis for applying consistent assumptions about the economic environment and would allow net trade to be a conclusion rather than an assumption of the study.

A variant of the gap model—Another variant of the gap model is illustrated by a study done to assess the demand for National Forest timber in Alaska (Haynes and Brooks 1990).¹⁰ As background, the State of Alaska has many characteristics of a developing economy. The state is highly dependent on resource extraction and primary industries (forestry, fisheries, oil, and gas development), and natural resource wealth is seen as the primary engine of economic development. In addition, most production is sold to external markets. Managers of public forest resources are challenged in Alaska to ensure that the mix of products satisfies public needs and that costs are balanced by present or future returns.

The model used is a simple, spreadsheet-based one that estimates the derived demand for Alaska National Forest timber in three stages: (1) estimates, by product, of Alaska forest products output; (2) the raw material requirements necessary to support this production (calculated by using explicit product recovery and conversion factors); and (3) harvest by type of landowner computed by subtracting projections of timber harvest by private owners and harvest by non-National Forest public owners from the total raw material requirements (after adjustments for log and chip imports). It is based on the following aggregate relation for stumpage demand (d):

$$d = k^l s^l k^p p^p + LE, \quad (1)$$

where

k^l and k^p are product recovery factors for lumber and pulp,

s^l is lumber output,

p^p is pulp output, and

LE is log exports.

The result of this model was an estimate of the volume of National Forest timber necessary to balance demand, given the explicit assumptions about markets (see fig. 1) and the implicit assumptions about prices.

¹⁰ This analysis of the timber situation in Alaska was done in support of the Tongass National Forest land management planning process

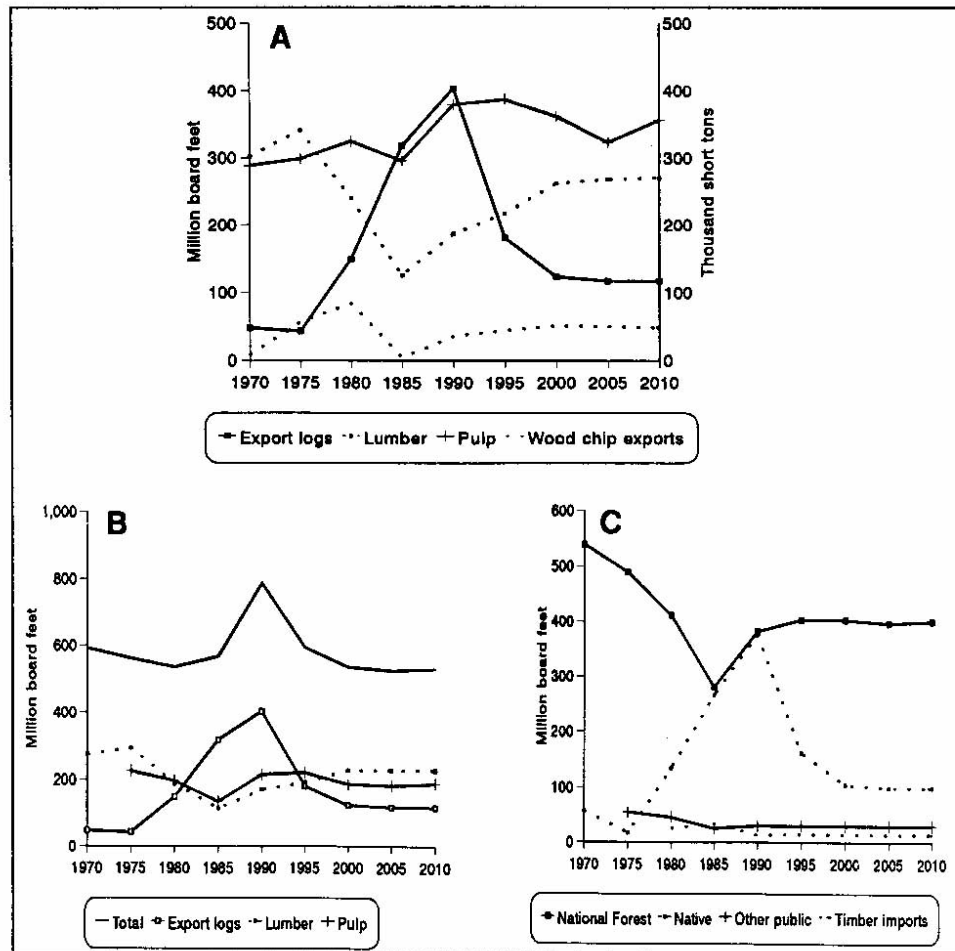


Figure 1—The Alaska forest sector, logs and lumber in million board feet, pulp and wood chips in thousand tons (A) Forest products, (B) timber harvest by product, (C) timber harvest by owner

This model satisfies economic principles in that production equals consumption (with adjustments for trade), and it satisfies material-accounting principles in that raw material requirements (derived demand) consider all products and conversion efficiency. Like most forest sector models, this approach assumes that demand for products is the primary determinant of the quantity and type of products produced. Because little of Alaska production is consumed in the State, expected developments in Japanese markets underlie projections for Alaska. Alaska's share of offshore markets is projected, and production is assumed to be equal to this quantity. Similarly, supply is assumed to be equal to the derived demand for raw material in raw material markets. Given assumptions (exogenous projections) of supply from other owners, the derived demand for National Forest timber can be computed.

The model was based on limited historical data describing relevant components of the Alaska forest sector. Possible future timber harvests were computed by using an analysis of trends in factors that determine harvests. The historical period 1965 to 1988 was used as the basis for a projection of nearly comparable length. This effort to balance hindsight and foresight was used to avoid undue emphasis on the short-term cycles—both boom and bust—that the Alaska market is subject to. Sharp cycles, triggered by changes in demand, are characteristic of the forest sector. Data for the historical period also were used to confirm the estimates of conversion factors and to validate the methodology for computing derived demand.

The method used to make these projections did not compute equilibrium values for prices and quantities; in fact, no explicit reference is made to prices. This was an elaborate trend-based projection of quantities, in which trends in consumption or trends in exports were the driving assumptions. Alaska markets (or any other) will adjust, through changes in consumption and supply by private owners, to any level of supply by public owners. Prices are the mechanism by which the need for these adjustments is indicated. Because planned timber harvests from public lands generally do not depend on prices, but are dependent on policies and multiple objectives, the quantity of National Forest timber necessary to balance the market was computed as a residual.

Analysts in developing countries will perhaps find this the most useful example of a simple model, designed to answer straightforward questions. The model was developed from a set of data fundamental to any analysis of a forest sector (quantities produced and traded), and the data were examined in a now widely available format: a microcomputer spreadsheet. It is also an example of a model that easily can be made more elaborate. Projections of consumption and production, for example, can be made to depend on prices and costs, rather than on the simple trends in market shares that were used. These elaborations can be made while the basic framework of the analysis is maintained.

The timber assessment market model—In the 1970s, the Forest Service developed a forest sector model for the behavior of regional prices, consumption, and production in both stumpage and product markets. This is the timber assessment model (TAMM, Adams and Haynes 1980), which has been used for the past decade to provide forecasts of market activity and to explore the need for and consequences of various policy actions

TAMM provides an integrated structure for considering the behavior of regional prices, consumption, and production in both stumpage and product markets. It is designed to provide long-term projections of price, consumption, and production trends and to simulate the effects of alternative forest policies and programs. To an extent far greater than was possible in the past, the use of TAMM has focused attention on the dependence of projections on (exogenous) input assumptions. In Forest Service assessments, these assumptions include the major determinants of the supply and the demand for various forest products. This section provides a brief description of how TAMM operates. Details about the various input assumptions used in TAMM are described in Haynes (199C).

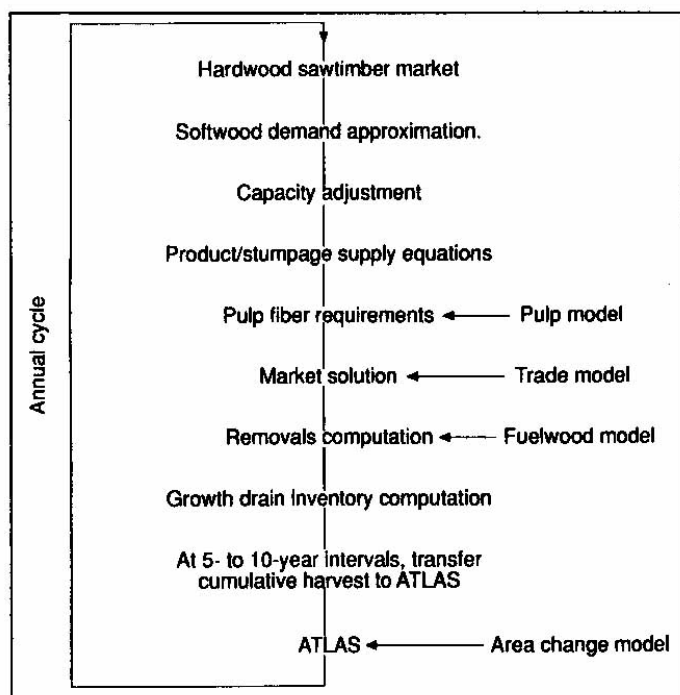


Figure 2—General structure of Tamm/Atlas model

The general structure of Tamm is shown in figure 2. It is composed of 10 major parts with exogenous inputs from four other models (pulp, trade, fuelwood, and area change). Briefly, product demand, such as softwood lumber, is obtained by multiplying the ratio of product use per unit of activity (such as the number of housing starts) and the number of units and summing these results over all various end uses for the product. The activity measures are exogenous and generally are taken from long-term macroeconomic forecasts. Unlike supply relations, which are compiled regionally, demand functions are compiled nationally. An example demand function (ignoring the time subscript) is given by the expression,

$$Q_i = \sum_u F_{i,u}(P_i, P^s_{i,u}, S_u) * Z_u, \quad (2)$$

where

Q_i is the consumption for product i ,

$F_{i,u}$ represent end use (u) factors as a function of their several arguments,

P_i the price of product i ,

$P^s_{i,u}$ is a vector of prices of substitute materials in end use u ,

S_u is a vector of other shifters, and

Z_u is a measure of activity in end use u .

The demand relations are regionalized by accounting for differences in regional per capita consumption and the ratio of regional prices to national prices. The product supply equations (ignoring the regional subscript) are estimated in the form,

$$Q_s = F[(P - C), K] , \quad (3)$$

where

Q_s is the supply volume,

P is the product price,

C is the average variable cost, and

K is the installed capacity.

Average variable costs are composed of wood and nonwood elements converted to a unit output basis by means of product recovery and productivity factors reflecting the current (or projected) conversion efficiency of the industry. Each product supply function includes installed capacity as a proxy for capital stock. Shifts in installed capacity are modeled as a function of anticipated changes in relative regional profitability or rate of return. Timber supply is modeled as a function of stumpage price and timber inventory. Finally, timber demand functions are derived from product supply functions by means of product recovery factors. Pulp fiber requirements are derived from a pulp model developed by Ince (in press). Trade and fuelwood projections (except softwood lumber imports from Canada) also are developed from analysis external to the TAMM system.¹¹

The remaining steps in the annual cycle of TAMM involve timber supply computations and an inventory projection system (ATLAS; Mills and Kincaid 1992). ATLAS is an age-based, yield table system that projects acres by detailed strata for periods consistent with the inventory stand-age classes. In ATLAS, the inventory is represented by acreage cells classified by region, ownership, management type, management intensity, and age class. Major assumptions include yield functions, projections of timberland area change and assumptions linking harvest to removals from inventory. The basic economic representation of timber supply describes the supply of timber at any point in time as being a function of the private timber inventory levels, stumpage prices, and the amount of public harvest available at that time.

¹¹ See the 1989 RPA Timber Assessment for further details (Haynes 1990).

¹² The aggregate timberland assessment system was developed by Mills and Kincaid (1992). It considers only the timber inventory located on timberland producing or capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. Currently, areas qualifying as timberland have the capability of producing in excess of 20 cubic feet per acre per year of industrial wood in natural stands and may be inaccessible or inoperable, or both. Further, these models include only live trees of commercial species meeting specified standards of quality or vigor. Cull trees are excluded. When associated with volume, these growing stock inventories include only trees 5.0 inches in diameter at breast height and larger.

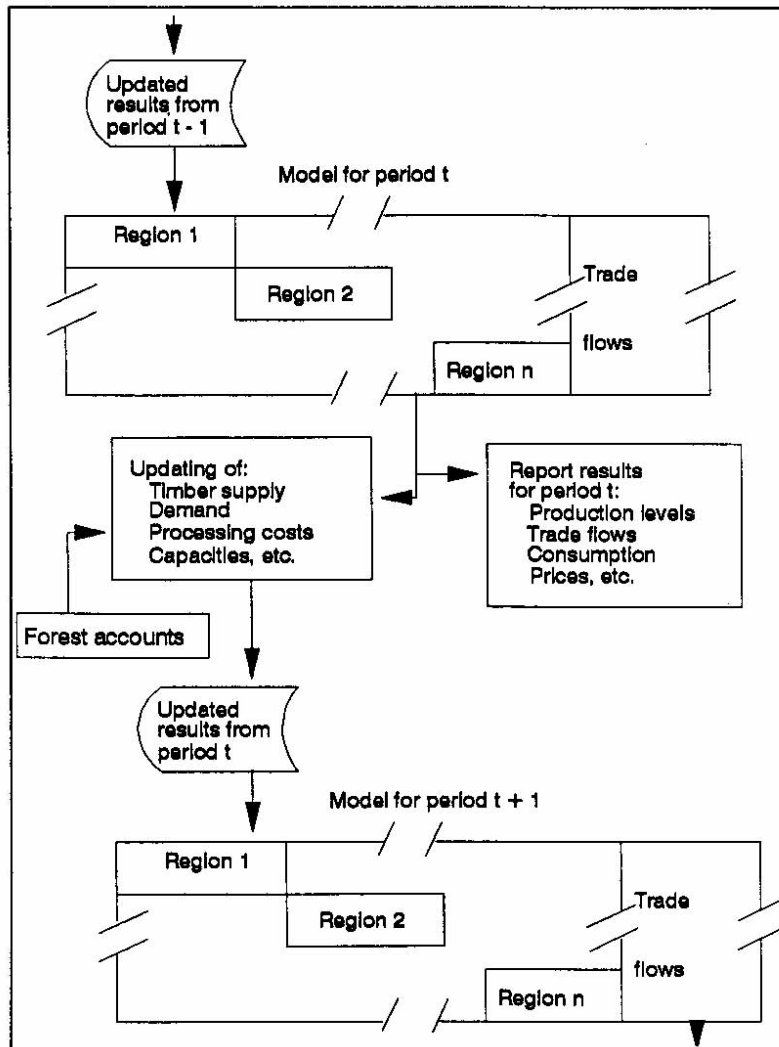


Figure 3—The CINTRAFOR global trade model

The solution of TAMM simulates a spatial equilibrium in the markets modeled for each year of the projection period. These solutions do not represent optimal decisions, and the basic market solution algorithm¹³ cannot be readily used to find intertemporal production or consumption strategies that are in some sense optimal. The production, consumption, and price time paths are only estimates of outcomes of contemporaneous interactions in freely competitive markets.

¹³ A revised reactive programming algorithm is used (Brooks and Kincaid 1987). Briefly, reactive programming is a method for solving continuous demand and supply function by successive adjustment of quantities produced and their distribution to demand regions to maximize producer profits net of transport costs in each supply region.

The CINTRAFOR global trade model—The CINTRAFOR global trade model¹⁴ (CGTM) is the result of 8 years of research at the International Institute of Applied Systems Analysis (IIASA) and continuing work at the University of Washington. The model projects production, consumption, prices, and trade for 10 forest products in 43 (supply and demand) regions that the world has been artificially divided into. Figure 3 describes the various components of the model. When given the demand and supply for each region, bilateral trade flows among regions, and transportation costs, the model solves for an equilibrium price, production, consumption, and trade flow. Equilibrium results for a base year are used to find equilibrium solutions for subsequent years by considering changes in demand, production, and trade levels. These changes are implemented through submodels for timber growth, production capacity, and consumption. A detailed description of the model is presented in Kallio and others (1987) and Cardellicchio and others (1988, 1989).

The CGTM utilizes the mathematical programming approach suggested by Samuelson (1952) and incorporated by Kallio and others (1987) in the IIASA forest sector model. A partial equilibrium solution is found by summing consumer plus producer surplus minus transportation costs. Constraints working on the model are (1) materials balance—in each region for each commodity, consumption equals production minus net exports; and (2) production capacity—production levels lie within the industrial capacity of each region.

Ten products are considered in the model: coniferous and nonconiferous saw logs, coniferous and nonconiferous pulpwood, coniferous and nonconiferous sawnwood, coniferous and nonconiferous plywood, reconstituted panels, and wood pulp. The last two products are inputs to the model.

The regional breakdown in the model is the most complete for a global forest sector model. There are 33 final product demand regions around the globe. Many regions have estimated demand functions for sawn wood and plywood. Final product demand is specified in constant-elasticity form by using one of the following equations:

$$Q/Z = a \cdot P^b \text{ or} \quad (4)$$

$$Q = a \cdot P^b \cdot Z^d, \quad (5)$$

where

Q is the product consumption (million m³ of product),

Z is an exogenous indicator of market activity (for example, GDP or housing starts),

P is the product price (real local currency per m³ of product), and

a, b, and d are estimated parameters.

¹⁴ This section was written by John Perez-Garcia at CINTRAFOR, University of Washington, Seattle

The final product supply specification is:

$$P = C + a \cdot U^b, \quad (6)$$

$$C = (p + HD) \cdot R_1 + MVMC - P_{CH} \cdot R_2. \text{ and} \quad (7)$$

$$U = Q_s / K^{-1}, \quad (8)$$

where

P is the product price (real value per m³ of product),

C is variable production cost (real value per m³ of product),

U is capacity utilization,

a and b are estimated parameters,

p is stumpage cost (real value per m³ of log),

HD is log harvest and delivery cost (real value per m³ of log),

R₁ is an input-output coefficient (m³ of log used per m³ of product),

MVMC is minimum variable manufacturing cost (real value per m³ of product),

P_{CH} is the price of wood chips (real value per m³ of chips),

R₂ is an input-output coefficient (m³ of product),

Q_s is product output (million m³ of product), and

K⁻¹ is production capacity at the end of the previous year (million m³ of product).

As in most forest sector models, the supply specification assumes fixed proportions: a unit of output requires fixed proportions of inputs, that is, inputs, (labor, capital, and raw material such as timber) are consumed in fixed proportions to each other and to product output

In the CGTM, changes in production capacity are made on the basis of historical profitability. A decision rule is employed to handle capacity expansion and contraction: if capacity is less than optimal, it expands, otherwise it contracts. The optimal capacity level is determined by defining a target capacity utilization.

Log cost is defined as the sum of two components: (1) the cost of stumpage or standing timber, and (2) the cost of harvesting the timber and delivering it to a mill. Not all regions have both the stumpage and the harvest and delivery cost structure. The decision on whether to model stumpage or harvest and delivery prices separately depends on their shares of delivered log prices, the availability of data, and the success of estimation. Stumpage supply is modeled as,

$$p = a(q_s/l)^b \text{ or} \quad (9)$$

$$P/P_{\text{bar}} = a(q_s/V)^b, \quad (10)$$

where

p is the stumpage price (real value per m³ of wood),

p_{bar} is a 3-year moving average of past stumpage sales prices,

q_s is the stumpage supply (million m³ of wood),

I is the growing stock volume (million m^3 of wood),

a and b are estimated parameters, and

V is uncut volume in public forests.

Changes in inventory levels are assumed to result in a one-to-one change in stumpage supply (the inventory elasticity is equal to one), as expressed in the stumpage supply equation.

The timber supply relations are shifted from period to period by using a growth-drain identity to update inventory:

$$I_{t+1} = I_t + G_t - H_t, \quad (11)$$

where

G is timber growth (million m^3 of wood), and

H is timber harvest (million m^3 of wood)

These dynamic elements of CGTM allow model solutions to be linked among time periods but do not imply an optimal inter-temporal market equilibrium solution. The dynamic structure in the model captures many of the adjustments that would be expected in a more complete presentation of the forest sector.

Forest Sector Analysis in Developing Countries¹⁵

Forest sector analysis in the Third World has a short history and has been largely descriptive. Perceived failures of forest-based industrial projects coupled with rapid deforestation in developing countries (most of which are in the tropics) has led to increased concern about the global environment and the ability of the Third World to sustain its explosive population in the near future. These concerns in turn have led to a burst of theoretical discussions on tropical forestry issues, which resulted in a global campaign in the 1980s. The campaign since has evolved into the Tropical Forestry Action Plan (TFAP). This plan was engineered mainly by FAO, the World Bank, and the World Resource Institute; it is the most ambitious environmental action plan ever launched on a global scale (Winterbottom 1990).

Despite these widespread concerns about deforestation and failures of forest-based industrial projects in the Third World, few formal analytical studies of the forest sector are available. Furthermore, the few formal studies that exist have been conducted under questionable assumptions and severe data restrictions.

The objective of this section is twofold: first, to review the recent literature on forest sector analysis in developing countries, and second, to evaluate these studies based on their contributions to the objectives of forest sector analysis. The review focuses on published works because unpublished studies are not readily available.

¹⁵ This section was condensed from a background paper written by Atse M. Yapi, a graduate student in agricultural economics at Oregon State University, Corvallis, OR 97331-3601. On file with: Social and Economics Value Program, Forestry Sciences Laboratory, Pacific Northwest Research Station, P.O. Box 3890, Portland, OR 97208-3890

Gap models—Gap models typically attempt to quantify the gap between the potential demand for and supply of different forest products over time at current price levels. Aggregate consumption and production at either the national or regional level often are considered in place of demand and supply per se. And for a given price level, a gap between consumption and production is forecast. Next, policies and programs are proposed to fill the gap.

The key advantage of gap modeling is its great flexibility in accommodating different levels of data availability. It is perhaps this feature that has made the gap approach the most popular method in developing countries where trained professionals and statistics on forest sector are very limited (Harou 1992).

The gap modeling approach has been very popular as an analytical framework in analyzing forest sectors in developing countries. To stress the popularity of the framework, Constantino (1992) writes, "As a matter of fact, even if a higher degree of economic sophistication is sought in the analytical exercise, it is most useful to always go through the gap stage and then proceed from there." Examples of gap models abound in forest sector reviews either conducted or cosponsored by FAO, the World Bank, and national governments.

Enabor and Umeh (1992) present three gap-type studies of the forest sector of Nigeria conducted by FAO in 1979, the World Bank in 1983, and the Nigerian Green Revolution Committee in 1983. All three studies were commissioned by the Federal Government of Nigeria. The main objective was collecting and treating technical and economic data on forest resource conditions and uses to assess future forest resource requirements of the country relative to possible future supply trends. Interestingly enough, all three studies arrived at the same major finding: the forest product needs of Nigeria are unlikely to be met within the country in the near future because the natural forests will very likely be exhausted before long. The consequent recommendations made by FAO and the World Bank include strict forest management with special emphasis on plantations for fuelwood and industrial wood. The study by the Green Revolution Committee reported, however, that the intensive forest management concentrated so much on artificial regeneration of forests that the management of natural forests was neglected. Later in 1987, Enabor evaluated the demand and supply trends of forest products in Nigeria and concluded that external sources of supply very likely would be sought to meet forest product requirements in the country (Enabor 1987).

The forest sector development planning model developed by Buongiorno and others (1981) for Indonesia can be loosely considered as a gap-type model. Although advanced mathematical programming techniques were used, the basic structure of the model was designed to determine patterns of timber and timber product supplies that would be consistent with given levels of domestic demands and exports of wood products.

Buongiorno (1992) reports his experiences with forestry sector planning models from Malaysia and Nigeria. These two case studies have many features of a gap model. The model for Malaysia uses six development strategies, which consist of six different rates of conversion of forest lands to agriculture. By simulation, the model identifies the best strategy to satisfy domestic and export demands of wood and wood products given log production data. There is no explicit objective function in the model; therefore, a set of criteria is used to evaluate alternative development strategies. But the final policy decision is a "compromise reflecting many socio-political considerations, weeding out the least promising strategies by debating them." The model for Nigeria is a timber demand and supply model designed not to determine equilibrium prices and quantities, but to identify investment strategies in the forest sector. Future requirements for and supplies of timber products are forecast by using current consumption and production trends. Then, investments most likely to fill the gap between expected future demands and supplies at minimum costs are determined. The gap analysis is conducted for fuelwood, poles, saw logs, veneer logs, industrial residues, and pulpwood.

Gap models are conceptually simple. They are, in fact, simple ways of organizing data and presenting results that easily could be explained and understood by lay people concerned with forestry policies. The simplicity of the gap framework and its great flexibility in accommodating different levels of data are the key advantages that made the method so popular in developing countries with limited statistics and trained professionals. The possibility for errors is great with gap models, however; they often are based on the assumption that the levels of forest product exports will be maintained over time when the gap between expected demands and supplies in a given country is calculated, and this assumption may not hold throughout the projection period.

Another shortcoming of the gap modeling approach is its inability to guide the implementation of the recommended policies. Gap models are excellent in establishing policies. But establishment of policy is one thing and policy implementation is quite another. This is important. For example, the above gap analysis for Nigeria revealed an urgent need for an intensive forest management policy with emphasis on reservation and regeneration. The implementation of this policy, however, took the forms of (1) an ambitious expansion of the area under reservation from 10 to 25 percent of the total forest area, and (2) a decision to reforest each year an area at least equal to that deforested (Enabor and Umeh 1992). Enabor and Umeh (1992) point out that both the rate of expansion of the reservation area and the reforestation decision were unrealistic, given (1) the land use and ownership patterns existing in Nigeria,¹⁶ and (2) the country's financial and technical capabilities to regenerate the forest resources

¹⁶ Unlike French-speaking Africa, where forest law can declare any unoccupied forest land state property (although local populations could still exercise many usage rights), Nigerian forest regulations fully recognize the claims of local populations to forest ownership. Thus, forests cannot be gazetted as state forests without prior consultation with local representatives. This consultation process may be time consuming and uncertain in outcome, thus the prospect of any ambitious reforestation plan is reduced.

Market equilibrium models—Market equilibrium models are characterized by a supply and demand adjustment process, which endogenously determines both price and quantity. Adams and Haynes (1987) distinguish three types of market equilibrium models: (1) nonspatial market equilibrium models, where only one country or region is considered; (2) quasi-spatial market equilibrium models, where goods flow only in one direction (from one region to another region); and (3) spatial market equilibrium models, where various spatially isolated markets compete among themselves. Market equilibrium models have been developed and successfully applied to the forest sector in developed market economies, especially in North America. It is hoped that as forest statistics and technical expertise improve in developing countries, market equilibrium models could develop and supplement the basic gap models.

Market equilibrium modeling approaches have been applied in several cases to the forest sector in developing economies: the Vincent study (1987) on Japan-South Sea trade in forest products, the Adams study (1985) on the African-European trade in tropical logs and sawn wood, and the Vincent (1992b) simple trade model.

Both the Adams (1985) and Vincent (1987) studies are competitive spatial equilibrium models designed to address trade issues, such as the impacts of trade barriers and exchange rates policies on trade patterns as they relate to national welfare. Adams's model serves as a guide to Vincent's model, and both use the same solution algorithm—reactive programming. Vincent's study was less aggregative than Adams's, however; Vincent considered individual countries (Japan, Indonesia, Malaysia, and the Philippines) as trading partners, but Adams grouped individual countries into regions as trading partners.⁷⁷

Vincent's (1992b) simple trade model is a nonspatial modeling approach that could prove useful for analyzing forest-products trade policies in developing countries. This model is simple because, according to the author, it can be developed and analyzed in less than 24 hours. The framework does not estimate functional forms for demand and supply but relies on predetermined estimates of demand and supply elasticities. This probably explains the simplicity and the quickness of the model. It is nonspatial (that is, does not determine bilateral trade flows) but does predict net trade balances. Vincent applied the model to analyze how log-export restrictions affected peninsular Malaysia. Model solution was obtained by using the Gauss-Seidel procedure; but the author insisted that the model was solved almost instantaneously.

Applying market equilibrium models in developing countries is more challenging than applying gap models as they require not only the adoption of assumptions difficult to justify even theoretically, but also the use of many proxy variables and incomplete

⁷⁷ Adams considered the following three regions: West Africa comprising Angola, Benin, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Liberia, Nigeria, Senegal, Sierra Leone, and Togo; Central Africa comprising Cameroon, Central African Republic, Congo, Equatorial Guinea, Gabon, and Zaire; and East Africa comprising Kenya, Madagascar, Mauritius, Reunion, Tanzania, and Uganda.

time series. For example, Adams (1985) justified his use of the competitive market framework by assuming that such a behavior may exist among countries rather than within individual countries. Also, because of data limitation, he adopted demand and supply equations that are not only crude but are also aggregated over countries that differ quite substantially from one another. For these reasons, results may be unreliable; and for individual countries, they may bear little or no relevancy at all. Nevertheless, the results produced by these competitive models cannot be overlooked. At a minimum, they provide preliminary results to compare with future research results.

General equilibrium models—General equilibrium (GE) models are multisectoral models. They are useful because of their ability to capture the intersectoral economic adjustments whenever they exist in the economy. Input-output (I-O) models are perhaps the best known models and convey the idea behind general equilibrium to a certain degree. But unlike I-O models, GE models have the distinguishing feature of being able to handle, among other things, nonlinearity in production technologies, optimizing behavior by consumers as well as producers, and price adjustment mechanisms (Vincent 1992a). General equilibrium models often are referred to as computable general equilibrium (CGE) models, perhaps to make them less intimidating and more accessible. Occasionally, CGE models have been advocated as a viable alternative to forest sector analysis.

The importance of the links between the forest sector and the rest of the macro-economy has been the driving force in arguing for the use of CGE in developing countries. Constantino (1992), for example, argues that the forest sector has become such a major part of the Indonesian economy that it would no longer be feasible to treat the sector as exogenous from the macroeconomy. Changes in the forest sector, he asserts, are likely to cause changes in other sectors of the economy.

Vincent (1992a) sees most environmental problems stemming from forest industrial development in developing countries as related more to nonforestry policy failures than to the forest products industry itself. Consequently, he advocates the use of CGE models, not as substitute for forest sector models, but as a "best available alternative" to forest sector analysis, provided that the forest sector is significant in the country's economy, so that the economic adjustments between different sectors of the economy could be adequately captured.

The framework for CGE has been used a few times to analyze the impacts of selected policies on the forest sector in developing countries. Most of these studies unfortunately have been recorded as unpublished reports. Vincent (1992a) mentions four such studies.¹⁸

¹⁸ See Vincent (1992a) for references to these unpublished reports.

The application of CGE models to forestry issues in developing countries is quite appealing, especially in those countries where forest sectors command important shares in foreign exchange earnings, employment, and contribution to gross domestic products. As data availability and technical expertise develop, CGE models also could develop to supplement forest sector models in developing countries. But as it is, the applicability of CGE models to forestry analysis in developing countries is likely to remain limited for many years. Even in developed countries, their application to macroeconomic issues is not without controversy (Vincent 1992a). Most CGE models are fairly complex, leading to the question of whether they could be easily understood by the policymakers likely to use them. And they are mostly static. This may limit their ability to analyze dynamic processes characteristic of a natural resource sector such as the forest sector. Finally, with the rapid depletion of forest resources in developing countries, it seems likely that the share of forest sectors will decrease over time. If so, then CGE models will become less and less relevant as a tool for forest sector analysis in developing countries.

Data needs—What seems to be most lacking in developing countries are the data necessary to develop complete forest sector models. World Bank and FAO data sources are helpful, but they concern mostly international trade variables with virtually no reference to internal market factors such as prices and quantities of forest products and other commodities of interest traded on local markets. Analysts therefore have no alternative but to rely on data of questionable quality from unreliable sources. This limits the confidence that can be placed on the estimates and predictions produced by the models. In this context, Buongiorno and others (1981) warn in their conclusion, "because the data are still crude, this paper must be viewed as a description of methodology rather than as a recommendation for policy." Adams (1985) also cautions about the results of his effort saying, "bilateral trade flows, as determined by the competitive spatial equilibrium model, appear to be generally consistent with the limited available flow data for 1980, though further testing of the results is clearly needed." Vincent (1987) is no exception. He found that data from sources other than the FAO Yearbook, especially sources from within the South Seas nations themselves, should be sought. Better data exist, but they can be accessed only by doing research in the nations themselves or by establishing cooperative links with researchers in those nations. Once the data problems are brought under control, then more attention can be given to other problems, such as the appropriateness of theoretical specification and associated solution procedures.

In addition to changing methodological approaches, there also has been an evolution in the use of models in strategic planning by both government and nongovernment organizations. This is particularly evident in the use of simulation techniques to analyze alternative futures and management strategies. One goal of these efforts is to derive useful information that can improve and expand the perceptions held by land managers and the public. As such, the approach differs from traditional modeling (and particularly forecasting) approaches by both treating uncertainty directly in the analysis and stressing the information needs of the public.

Impact of Strategic Planning

In the modeling literature, this approach has been called scenario planning (Wack 1985). Scenario planning, as it is usually applied, does not attempt to predict the future. Instead it postulates a set of plausible futures, each dependent on the assumptions underlying that future. By doing so, the technique focuses on what might happen (positive or negative) and how to deal with it. This can be contrasted with planning for predetermined future. Scenario planning has been around in both the general literature and forestry literature since the mid 1980s.⁷⁹ Some of the earlier applications dealt with the turbulent oil markets of the 1970s (Wack 1985, Schwartz 1991). In forestry, scenario planning techniques have been a part of the RPA efforts since the 1983 RPA timber assessment update (Haynes 1990, USDA Forest Service 1982). Most forestry applications take a classical sensitivity analysis approach, a limited number of key exogenous and endogenous elements are varied and key projection results examined for differences. These differences allow the identification of emerging problems and provide a way to measure the effectiveness of possible solutions to various problems.

In scenario planning as used in forestry, there are four types of information—endogenous variables, two classes of exogenous variables, and model coefficients. First, the endogenous variables are those determined in model solutions. In forest sector models, these typically include product and stumpage prices, consumption and production levels, and levels of timber harvest and resource conditions (and levels) by owners. There are two classes of exogenous variables. One class includes those predetermined variables that will not be influenced by events within the system being modeled. The second class of exogenous variables includes those variables whose values could change depending on what might happen within the system being modeled or where outside forces could intervene to change them. The first type of exogenous variable might include variables such as gross national product (GNP), housing starts, or projections of timberland area. The second class of exogenous variables represents input assumptions that are less certain. In forestry, these might include levels of public timber harvest, export policies, growth and yield representation, stand transition matrixes, and so forth. This last type of variable also is called a policy variable. In that interpretation, these variables are under the control of those doing the systems modeling and are used to introduce into the various biological and social processes changes that lead to different values for the endogenous variables. In forestry models and elsewhere, exogenous variables often are referred to as assumptions.

The fourth category of information includes all model coefficients. In model-building terms, these are a special class of exogenous variables. These often are the least manipulated variables, and they usually are developed and tested independently of each other. Finally, one truth to remember is that the endogenous variables are the consequences of the assumptions. Changes in assumptions, in the case of forest sector models, will change our view of prospective market changes.

⁷⁹ Prior to the mid-1980s, these same techniques were described in the simulation literature as a policy simulations approach (Naylor 1970). At that time, the simulation approach was seen as having an advantage over the more commonly applied optimization approaches in that it did not require knowledge about the policymaker's welfare preferences or particular targets but provided the policymaker with information necessary for decisionmaking.

The models used in these types of applications usually are called systems models, and many forest sector models fit the general form. The basic systems model can be written as,

$$Y_t = N_{1t}Y_{t-1} + N_{2t} \begin{bmatrix} X_t \\ Z_t \end{bmatrix} + V_t, \quad (12)$$

where

Y_t is a vector of current endogenous variables,

Y_{t-1} is a vector of lagged endogenous variables,

X_t is a vector of predetermined exogenous variables,

Z_t is a vector of postulated exogenous variables, and

V_t is a vector of stochastic disturbance terms.

Vectors N_{1t} and N_{2t} are model coefficients. Model solution involves solving for Y_t in terms of Y_{t-1} , X_t , Z_t , and V_t . Given X_t and Z_t , evolutionary behavior can be explored in which the model generates its own values for the endogenous variable Y_t over many future periods. By manipulating the values of the postulated exogenous variables Z_t , the time paths of the endogenous variables are determined for each alternative policy.

Applications of TAMM and the CGTM to Developing Countries

In unmodified form, models such as TAMM and the CGTM are not applicable as planning and projection models to the conditions of most developing countries. In TAMM for example, implementation of its demand and supply elements, at both the product and stumpage levels, requires data not generally collected in developing countries. The focus of TAMM is primarily on (U.S.) domestic market conditions, intracountry trade, and competition among essentially independent producing regions for a spatially dispersed consumer market. External trade is treated as an "input" to an elaborate model of the domestic sector. In contrast, external trade usually, though not always, is critical in the forestry planning of developing countries. Regional differences may be important on the production side but not so critical on the demand side (excepting some of the very largest developing nations). TAMM employs the economist's classical competitive market structure as the context for market resolution and establishment of a trade equilibrium. This view of the trading environment (as competitive, organized, and operating entirely within appropriate legal structures) may not be a reasonable representation of some developing countries.²⁰ Finally, TAMM is a simulation model. It could be employed in some programming framework to determine "optimal" public policies, but it was not designed for this approach to policy analysis and its structure would make such an application cumbersome.

²⁰ A developing country's "industrial" (primarily export) economy may operate in this way, that is, analogous to the economy of a developed, market nation, but the means by which goods are produced and distributed to the indigenous and often highly dispersed populations in rural areas may be quite different. It also is evident that in some countries, large volumes of wood flow from forest to market through strictly extra-legal channels.

The basic philosophy behind TAMM and its associated policy planning process nonetheless would seem to be of considerable potential value. For purposes of development planning, the key feature that distinguishes TAMM from earlier market modeling efforts is its linkage of the product and resource levels in a way that allows interaction among resource growth and inventories, market behavior, and policy actions at both the market and resource levels. For planning in developing countries that will at least consider, if not emphasize, stewardship or maintenance of the productivity of the resource base, this approach would seem to be mandatory. Construction of each model component must be tailored to the specific conditions of the country in question and the goals of the planning effort, but some general guidelines can be adduced.

The basic resource model should provide a reasonable representation of both the biology of the forests in question and of the form and effects of human intervention and actions. In the current version of TAMM, use of an age class-based inventory model with density-dependent yield functions has, to this point, proven satisfactory. Regeneration activities and additions to the timberland base are among the most important actions in terms of influencing long-term timber supply. The age-class format handles these changes well. But the model does not distinguish among species within a given forest type, and it only approximates stand responses to selection harvesting. These would be significant limitations in modeling the resource in, for example, a developing tropical country, where in some natural forests species differences are important and partial cutting the rule.

Concerns in the choice of form for the market portion of the model are no different from those faced by market modelers generally: aggregation of regions, sectors, and products; need for an explicit spatial structure; format of the modeling process (econometric simulation, price-endogenous linear or nonlinear programming); and the extent to which offshore trade should be made endogenous. The TAMM format has worked reasonably well for its specific situations. The broad issues involved here have been addressed in several excellent reviews of forest sector and trade modeling approaches, including Kallio and others (1987) and Cardellicchio and others (1987). The only useful caveat I can offer is the need to retain flexibility in the modeling approach in the face of the analyst's inevitable inability to foresee all types of policy questions likely to be asked. Indeed, the development and initial application of a model often raises new questions outside (or at the margins of) the abilities of the original structure. This is not to say that one must always build the ultimate model. Rather, that the bias in modeling be toward adoption of more, not less, flexible approaches where decisions arise in model construction.

Finally, a case needs to be made for the utility of market-sector simulation models, like TAMM, in the context of development planning. All too often, in my view, development studies entail only the construction of large optimizing models to provide blueprints for specific activities and expenditures. These studies focus heavily on the details of enactment of policies. At the same time, their outputs are seldom subject to any sort of "checking" for their impacts on the broader context of the forest sector. Thus, for example, a cost-minimizing or employment-maximizing development plan might be examined by a market simulation model for its impacts on trade, prices, consumption, and so forth. This is the general approach used in parts of the USDA Forest Service's land management planning process for the National Forests. Outputs from the plans (which are, in effect, resource development strategies for the individual forests) are examined by various market simulation models to better understand the interactions and impacts on other elements of the forest sector (such as private forest owners, trade, prices, and consumption). A similar approach in the context of planning for developing countries would seem to have equal merit.

Summary

The last decade has seen the development of forest-sector-model-based on systems analysis and quantitative economic techniques (developed since the 1950s.) Since the mid-1970s these models have been used to judge relevant policy issues and provide forecasts that are the primary components of long-term assessments prepared by various government and nongovernment organizations. These applications have overcome considerable skepticism on the use of models for forecasting and decisionmaking. But some skepticism continues, despite the appearance of analytical rigor, that policy recommendations are based on opinions rather than on robust analysis.

Continued evolution of forest sector models in the next decade will result in more elegant models in the sense that greater reliance will be placed on using theory to guide econometric and model specification. Coincidentally, evolution of strategic planning as a function of scenario planning will challenge analysts to explore ways to integrate analyses with intuition in the development and use of forest sector models.

The evolution of forest sector modeling has reached a stage of maturity where there is general agreement that such models should include treatment of the following elements:

1. Product demand
2. Product supply
3. Factor supply (often only wood supply is modeled)
4. Factor demand
5. An explanation of the forest resource (both timber inventory and the forestland base)

It is not necessary that all five components be present, but some implicit treatment of the missing elements should be included. The two general classes of forest sector models—gap and equilibrium models—fit this general approach. For summary purposes, various attributes of these two types of models are summarized in figure 4. A simple but actual policy-relevant example of both types of model is shown in appendix 1.

General Approach to Forest Sector Modeling

GAP MODELS	
Model component	
Product demand	Consumption by product, end use Usually treated in combination by converting production into roundwood equivalents
Product supply	
Stumpage demand	Usually a function of timber availability Extrapolations of past inventory trends, sometimes using the growth-drain identity
Stumpage supply	
Resource trends	Extrapolations of past trends, often with little distinction between product and stumpage markets
Prices	Primarily focuses on the difference (gap) between consumption and timber availability at a point in time
Policy measures	

EQUILIBRIUM MODELS	
Model component	
Product demand	Consumption by product, end use; includes product prices
Product supply	Production by product: includes capacity, costs, and prices
Stumpage demand	Treated as a derived demand
Stumpage supply	Usually a function of timber availability and stumpage or log prices
Resource trends	Extrapolations of past inventory trends, sometimes using the growth-drain identity
Prices	Endogenously computed; usually distinguishing product and stumpage market
Policy measures	Primarily various price trends and sometimes harvest and production levels

Figure 4—Attributes of two general classes of models.

This section begins with a brief summary of modeling philosophy and then discusses models attributes including examples of how models might be applied under different circumstances.

A Philosophy to Guide Model Building

Remember that models reflect the builder's values (and biases) and they are only a means to an end (a set of tools that can be used by an analyst). From an economics perspective, increasing quantification and precision in model building should not be allowed to narrow the focus and shift the underlying economic concerns away from its roots in the broad social science view of political economy.

Good model building is an evolutionary process, especially as models of fairly complete systems are dealt with (for reference these are called systems models). It is this understanding of evolutionary behavior and its dependence on assumptions that is important in systems modeling. Such systems models, although inexact, can and do provide a qualitative understanding of complex biological and social processes.

Some guidelines follow that are helpful in building system models.

1. Methods should be selected to fit problems (or systems); problems should not be distorted to fit methods.
2. Model testing or validation is critical; although there is no agreement on the necessary and sufficient rules for producing an overall evaluation, some useful suggestions for model validation include the ability to reproduce historical trends and turning points in selected variables. Another area where testing is critical is when models include complicated processes and it is difficult to predict a priori the effectiveness of various interventions to induce changes in selected endogenous variables. Only through repeated experiments can the model builder gauge the sensitivity of a model to various changes.
3. Models should be inherently complex and not simply produce as output a carbon copy (or barely modified version) of the various assumptions and exogenous projections provided as inputs; that is, models should not simply parrot their input assumptions. An important aspect of this is that although specific relations may seem simple (in a mathematical sense), such as a yield or a demand function, it is the links between that relation and all other relations in the model, expressed by changes in endogenous variables, that introduce model complexity.
4. Models should be robust. Robustness, as a semimathematical concept, is where the endogenous variables (the results) are relatively stable even "when assumptions are not quite satisfied" (Keepin 1984). The quality of robustness in models of biological and social systems deals with the sensitivity of the implications drawn from the results. If the implications change markedly with only slight changes in input assumptions, then the projection is not robust. The point is that careful sensitivity testing is required of all models, especially those with complex processes.
5. The utility of system models in providing insights and understanding of the behavior of forestry processes becomes even greater for long-term projections. It is in this context that the effects of various time-sensitive (dynamic) relations become critical; these dynamics must include consideration of different scenarios representing different views of the future, and a recognition of the inherent uncertainty of any projection. The future should be seen as a moving target. Understanding the uncertain nature of future events and making this uncertainty a part of the modeling process leads to a shift in focus of decision analysis away from concern for predicting outcomes toward understanding the forces that eventually produce an outcome.

This philosophy, generally shared among model builders, leads to some common expectations about the attributes to look for in sector models. Perhaps foremost is that models need to address the relevant questions, not the other way around. Models need to be as simple as possible and intuitively understandable. They need to contain relevant policy variables (or criteria). Good models are used. Models need to be developed at a geographic scale relevant to the eventual users, including those who will use the results in making decisions. Sometimes the major role of a model may be to systematically organize the description of a problem. Models must be robust, in that their ability to reflect basic structural changes is more important than superior analytical performance that assumes stability. It is better to have a simple model than none at all; this is especially true even when data are bad or limiting. In such a case, a model can help assess the value of improving or expanding the data in addition to providing information to decisionmakers and analysts.

The final point is to acknowledge that much of this section reflects the philosophical approach of "model simple, think complex" (Behn and Vaupel 1977). There is an alternative approach of building big monolithic models that seek to be comprehensive and serve many purposes. Such models lack transparency and aggravate problems associated with documentation, verification, and credibility. Increased detail is a poor substitute for imagination in model conceptualization. Modelers need to be careful that, in spite of their best intentions, forest sector models do not end up as big models because of pressure to add detail.

General Model Attributes

The starting point for any forest sector model is deciding what questions it might be used to answer. An honest appraisal of potential questions will help focus the scope of model building. Some key questions about model attributes that have to be answered at this stage include:

1. How much product detail (both commodity and noncommodity) is necessary?
2. What treatment of the stumpage or resource sector is appropriate?
3. How does national consumption (or the sum of regional consumption) relate to the rest of the world?
4. How important are prices and in what ways?
5. If prices matter, how are they determined (what market processes will be modeled)?
6. How will time be treated?
7. What variables are of interest to policymakers?
8. How will issues related to nontimber goods and environmental issues be treated?

By the end of the Paris meeting, there was general agreement that the simplest model and the model most universally applicable in developing countries is the gap model. This model and various applications were described in several proceedings papers from that meeting (Haynes and others 1992). Gap models have been an important step in the evolution of price equilibrium models as demonstrated by the experience in the United States. The gap model consists of several major attributes: product demand, product supply, stumpage supply, resource trends, prices, and policy measures (see fig. 4). In its most comprehensive form, the gap model differs from equilibrium models only in the treatment of prices.

In an economic sense, forest sector models represent the simultaneous solution of two competitive markets: the final product market and various factor markets (roundwood, labor, capital). In a practical sense, the various factor markets usually are reduced to just the roundwood market because neither the labor nor the capital market is limiting (or said another way, opportunities for substitution are greater). This distinction imposes some specification needs on the variables used in the empirical relations representing the various markets. The following discussion depends, too, on maintaining the distinction between product and factor markets.

Product demand—Product demand in the gap model can be treated in various ways including econometric approaches, subjective assumptions, and projections taken from exogenous sources such as FAO. Each approach is illustrated in various proceedings papers (see, for example, Constantino 1992, Lonnstedt and Peyron 1992, Sidabutar and Chandrasekharan 1992). Consumption figures can be adjusted for trade to get domestic (or regional) production. Another consideration is the spatial scale used in developing the demand estimates; for example, Do we attempt to estimate the national demand for sawn wood products? and How do we treat different species or subnational differences? The answers to these questions begin to define the scale and detail of the forest sector model. In the United States, much of the demand work is done nationally but differences in the demand for hardwood and softwood species are recognized as are differences in regional consumption. In an economic context, these demand relations are in the traditional form (quantity as a function of prices and exogenous shifters). Often these relations represent major consuming segments of the economy, such as housing or manufacturing. One approach is called the end-use model where, for example, wood use per house is estimated and total consumption is computed by multiplying that by the number of housing units expected to be built.

In addition to the end-use approach, several simple forms of the demand relations are used relatively widely. The first is a model derived from multiplying estimates of per capita consumption by expected population (a variant uses consumption per some unit of GNP). In this approach, trends in consumption are expressed by changes in per capita consumption. In Mexico, for example, per capita consumption for industrial uses and fuelwood averages 0.27 cubic meter per year. Wood use in Mexico has been increasing at the rate of 0.34 percent per year and is expected to rise by 2010 to 0.29 cubic meter per person. If we assume that Mexico's population will continue its relatively rapid rate of growth of 2.3 percent per year for the next two decades, total consumption will increase from 22.63 million cubic meters in 1989 to 39.65 million cubic meters in 2010.

Another model is called the FAO approach and was developed by Baudin and Lundberg (1987) and is best described by Baudin and Solberg (1989). The FAO approach generally can be described as a log-linear model of the form,

$$\ln Q = a_1 + b_1 \ln(Z_t) + u, \quad (13)$$

where Z_t is a vector of explanatory variables such as GNP or GDP and prices (measured by Baudin and Lundberg as the real unit border values for the largest trade flows).

For Mexico, the FAO approach would lead to the following equation for coniferous sawn wood:

$$\ln Q = 5.219 + 0.379 \ln \text{GDP} - 0.95 \ln \text{price}, \quad (14)$$

Such an equation has an adjusted R-square of 0.88 and significant terms except for price. The price term, however, has the correct sign. This example illustrates a common problem with price terms in demand relations for forest products. Because these products often are extremely inelastic, the implication for the price coefficients is that they are nearly zero. Given how small the coefficients may be, it is likely that the signs of the coefficient may be wrong. Another way to put this is that it is very likely that the price coefficient will vary around zero, thereby making it difficult to estimate both the correct sign and a significant variable in the same equation.

Product supply—In an economic context, product supply is the quantity of products produced as a function of prices and costs. Typical product supply functions are of the form (for sawn wood in this example),

$$Q_s = a_1 + b_1 * p_s + c_1 * Z', \quad (15)$$

where p_s is the price for sawn wood (preferably at the mill; that is, prices at the mill, FOB) and Z' includes explanatory variables, such as measures of processing costs, installed capacity, and so forth. In the case of costs, it is best, but also unusual, to have a measure of total processing costs. A more common approach is to use available measures of parts of the total costs, such as labor costs, or proxies, such as wage rates.

Again for Mexico, a supply function can be estimated in the form,

$$Q^s = -201771.3 + 0.235 \text{ price proxy} - 871.033 \text{ wages} + 104.95 \text{ year}. \quad (16)$$

The price proxy in equation (16) is the unit value of roundwood imports. Equation (16) has an adjusted R-square of 0.82 and most terms (except for wages) are significant. In general, the computed price elasticities for the supply relations are four to five times greater than the demand elasticity. This result is not unique to Mexico, as it also is seen in similar relations for the United States. This equation for roundwood production in Mexico also contains a time trend. Analysts often will try to interpret such variables as a proxy for technological change. Such an interpretation can lead to trouble because a time trend reflects a uniform rate of change while the adoption of technological change often is at a nonuniform rate (that is, takes places in bursts of activity).

Product supply, however, often is treated by converting expected consumption of each product into roundwood equivalents through the use of local conversion factors. Once in roundwood form, this is the derived consumption of roundwood for the selected country (if it included price terms, it would be a derived demand function).

Stumpage (roundwood) supply—This is usually treated as a function of timber availability and can be determined from forest regulation (harvest) models, government fiat, trends from the past decade, proportion of timber inventory or timberland area, and so forth. It also can be treated in an economic context where timber harvested (or delivered) is a function of timber prices, inventory characteristics, and other variables.

Often key variables in stumpage (roundwood) supply relations are various attributes that describe the inventory of available timber. Such attributes are total inventory, amount over minimum harvest age, average size (diameter), percentage of saw-timber, and so forth. The tendency is to want to add a number of such attributes to the relations, but experience suggests that most attributes are collinear and just the basic attributes work best. In countries such as the United States, stumpage (roundwood) supply functions are defined for different types of forest land-owners (public, forest industry, and nonindustrial) in an attempt to recognize different propensities in behavior. In this case, total supply is just the sum (in a linear sense) of the individual supply relations.

Resource trends—Often not present, but a key component of one of the selected issues, is sustainable forest development. The simplest models are stock adjustment models constructed around the basic growth-drain identity shown in equation (11). The model in equation (11) is the simplest form in which the inventory term is expressed as total inventory. A common variant of this model is to express the inventory on a per-hectare basis. This requires adding a variable for total area of forest land to the equation. Inventory models can become complex, as illustrated in the United States where an age-based, yield-table system is used that projects acres by detailed strata for periods consistent with the inventory stand-age classes.

The actual application of equation (11) is complicated by the treatment of forest land area, species differences, definition of what forest (and forest lands) are included in the inventory term, choice of time intervals, and relations between harvests and removals of timber from inventories (some harvest may be assumed to come from forest land or species not included in the definition of inventory).

In each simulation period, inventory change is the result of growth, change in the area of forest land, and timber harvest. Inputs to the inventory model include estimates of harvest, acreage shifts, and growth parameters. The levels of harvest are derived through interaction with the product components of the forest sector model. Assumptions about the changes in forest land area are a required input. Alig (1992) illustrates several different approaches to developing these assumptions.²⁷ Inventory data can be derived from timberland inventory plot data or from extensive aerial inventories.

I have used a real example to illustrate how the inventory identity can be used and how it can be integrated into a simple but functional forest sector model.²² A recent concern has been economic impacts of the possible introduction of defoliator insects in the U.S. West as a result of importing larch (*Larix* sp.) from Siberia and the former Soviet Far East. These economic impacts were estimated in a market context by using timber supply and demand relations (taken from the 1989 RPA timber assessment [Haynes 1990]) for the Pacific Northwest, Pacific Southwest, and the Rocky Mountains. Economic impacts were estimated by first computing the equilibrium price and quantity by decade and region, and then recomputing the modified equilibrium price and quantity following a shift in the stumpage supply functions, assumed to be induced by changes in growing stock inventories. Basic economic impacts are slow to develop and depend on the extent that inventories and, hence, timber supplies are reduced owing to less growth.

The supply and demand functions in the model are of the general form,

$$q_d = a_1 - a_2 p_s, \text{ and} \quad (17)$$

$$q_s = b_1 + b_2 p_s + b_3 I, \quad (18)$$

²¹ Palo (1987) proposes a scenario approach for developing assumptions about the area of forest land and rates of deforestation

²² This model was developed as part of the pest risk assessment of the importation of larch from Siberia and the former Soviet Far East (USDA Forest Service 1991)

where

qd and qs are the quantities demanded or supplied,

ps is the stumpage price, and

I is the timber inventory available for harvest.

This form for stumpage supply was adopted because inventory levels are one of the main determinants of stumpage supply. In the analysis, I assumed that defoliator insects will reduce net annual growth of selected species by 15 percent and that the rate of spread is 20 kilometers/year.

Graphically, the analysis involved shifting the stumpage supply functions back by the amount of change in softwood growing stock inventories that resulted from reduced forest growth, caused by introduction of defoliator insects. Changes in inventories act to shift stumpage supply functions in the longer term, and changes in prices help establish supply levels in the near term. These changes in inventories were computed by using a growth drain identity (equation 11); both the original and modified inventory numbers are shown in the following tabulation.

Year	Original			Modified	
	Inventory	Growth	Harvest	Inventory	Growth
<i>Million cubic feet</i>					
1990	116,713	2,784	2,714	116,713	2,784
2000	118,983	2,784	2,557	117,304	2,616
2010	119,983	2,784	2,684	114,909	2,445
2020	120,453	2,784	2,737	111,649	2,411
2030	120,303	2,784	2,799	107,768	2,411
2040	120,103	2,784	2,804	103,838	2,411

Solving the supply and demand functions for 2040, for both the original case (without defoliators) and the modified case (where the supply functions has been shifted by the ratio of original inventory to the modified inventory), shows that the 15-percent change in inventories results in a 10-percent increase in stumpage prices. Other economic measures, such as the welfare impacts and employment losses, can be computed from these results and were computed in the original application of this small forest sector model.

Prices—There are several ways to treat prices. The simplest is to deal with price trends descriptively, inferring continuation or change in those trends based on changes in the various quantity measures. A more complicated way, but more pleasing to economists, is to solve for price as the simultaneous solution of supply and demand functions.

Some concepts and aspects of price analysis are important in forest sector modeling. First there is the concept of price arbitrage; that is, prices of different species and grades of lumber for example, varying in some fixed proportion to each other or to roundwood prices. Arbitrage leads to conditions where prices of one species and grade will not exceed prices for other species and similar grades because of the possibilities of substitution. Another form of this arbitrage is between similar grades. In the United States, for example, this concept has been used to develop price projections for various grades of lumber (Haynes and Fight 1992).

Another persistent problem has been the relation between prices for finished products and the prices of factors used in producing that product. By definition, the return to a factor is an economic rent and presumes that the factor is fixed in supply, hence, the return to the factor is market determined and therefore consistent with market equilibrium concepts. Empirically, this implies that factor prices can be derived from product prices.

The above implication has important ramifications for policy analysis; for example, a government program affecting the supply (availability) of timber impacts the final product prices, but policy questions relate to changes in stumpage or roundwood prices. In agriculture, this same situation has led to empirical attempts to estimate the relation between farm level and final market prices. In various types of price analysis, some of these forms of arbitrage are institutionalized through what have been called price markup rules (George and King 1971). Classic examples might include the relations among prices for various grades of shop lumber. These rules have been used in past forestry studies (Haynes 1977) on the relation between lumber prices and stumpage prices and implications for the derived demand for stumpage.²³

These price markup rules are of the general form,

$$P_i = b_1 + b_2 p_j, \quad (19)$$

where P_i and p_j are prices of lumber and roundwood, in this case, and b_1 and b_2 are estimated coefficients. The significance of the estimated coefficients, b_1 and b_2 , makes a statement about the form of the relation between the two price series. It would be a fixed amount if b_2 was zero,²⁴ a constant proportion if b_1 was zero, or some combination if both b_1 and b_2 were nonzero coefficients. If equation (14) can be estimated and the coefficients b_1 and b_2 are significant, then the elasticity in the factor market (e_s) is given by the relation,

$$e_j = e_i [1/(1-b_2)] P_i / p_j. \quad (20)$$

Finally, the term $[1/(1-b_2)] P_i / p_j$ has been called the elasticity of price transmission (George and King 1971).

²³ In this case, price markup rules are called marketing margins and are an accepted descriptive model of the relation between factor and product markets

²⁴ In economic studies, the actual value of the b_2 coefficient, while different than zero but not statistically significant is interpreted as being zero

There are several practical problems related to prices that together or separately make estimating demand relations difficult. First, there is the lack of price data in many countries—data that represent consumer behavior. In many cases, the only price data collected are part of a country's trade data or "list" prices from importers or wholesalers. It is best when the price data reflect actual transactions as closely as possible to the final consumers. Second, it is difficult econometrically to estimate price coefficients that are both statistically significant and have the correct sign. The reason is that most demand elasticities in forestry are inelastic, so that the various price coefficients are close to zero. One alternative to this problem is to assume (or estimate independently) an elasticity and then, using the equation for elasticity and prices and quantity for a specified period, solve for the slope of the demand function.

Roundwood demand—In many forest sector models, the various comparisons for policy purposes are done in terms of roundwood volumes; that is, the volume of logs or other round products required to produce the lumber, plywood, wood pulp, paper and other similar products. Some call this relation the wood materials balance relation because it attempts to account for all roundwood used to produce the full array of forest products (see, for example, fig. 10.2 in USDA Forest Service 1982).

The conversion from product to roundwood measurement scales is one place where technology assumptions can be put in a forest sector model.²⁵ Over time, product recovery can be assumed to improve as the result of technological improvements. In models like the SOS model (Panders and others 1978), changes in technology is an endogenous process, but for the most part, it is treated as an exogenous variable.

Time intervals—Forest sector models typically are intertemporal and often based on discrete time intervals. One of the first questions is, What model elements (consumption, product production, capacity, or the resource situation) change with time? Another question is, How will the model builder deal with the different time intervals often found in different aspects of the forest sector? For example, market interactions usually are modeled annually, but inventory models often are specified by decade (depending if and how age classes are specified).

Gap models typically trace consumption and availability trajectories overtime, although specific gaps between the two trajectories are measured at specific points in time. The solution of equilibrium models represents an equilibrium in the markets modeled for each year of the projection period. These solutions often do not represent, and the basic market solution algorithm cannot be readily used to find, intertemporal production or consumption strategies that are in some sense optimal. The production, consumption, and price time paths in the equilibrium model are only estimates of outcomes of contemporaneous interactions in freely competitive markets. One alternative proposed by Lyon and Sedjo (1983) is the use of optimal control theory to trace the optimal transition path from old growth to managed stands through time. The control theory approach has not been widely used for modeling forest sectors.

²⁵ Other places where technology assumptions can be made include assumptions about wood use (for example, wood use per house) in demand relations and labor productivity assumptions that can be embedded in the cost assumptions

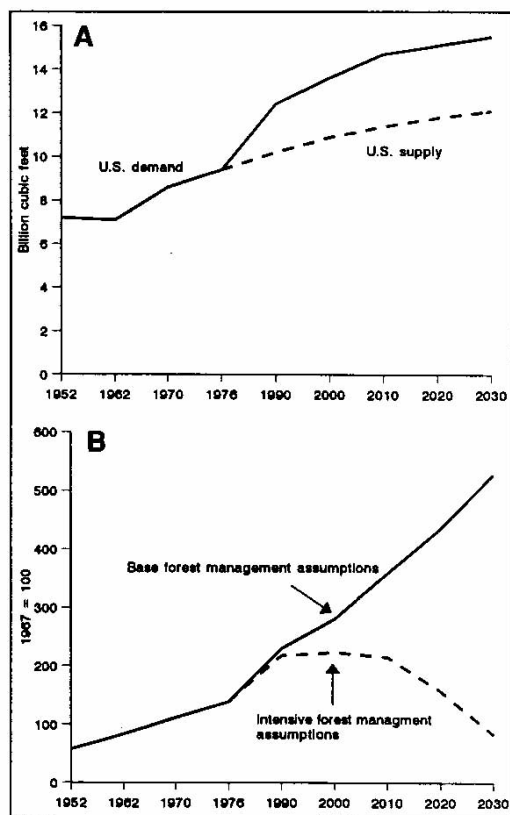


Figure 5—Example policy measures: (A) U.S. supply and demand and (B) stumpage price index.

Policy measures—There are two issues: the variables of interest to policymakers and how the effectiveness of policy actions will be judged. In gap models, the primary policy focus is on the difference (gap) between consumption and timber availability at specified points in time. In equilibrium models, various price and quantity variables are available for use as policy variables. The projected path of prices often is used to identify potential problems or to measure the effectiveness of specific policy actions including various forms of market interventions. Although not a feature of gap models, potential policy implications are associated with interpreting the solution of equilibrium models. First, although these solutions do not represent intertemporal production or consumption strategies that are in some sense optimal, they do represent how the markets might evolve from considerations of economic efficiency. Second, economic models allow the estimation of various welfare measures that can be used to address the economic equity questions of who gains and who loses.

These two issues are illustrated in figure 5 by using data from a Forest Service assessment (USDA Forest Service 1982). Figure 5a illustrates the results of a gap analysis for projected supply-demand balances for U.S. softwoods. Figure 5b illustrates a stumpage price projection for softwoods in the Southern States of the United States associated with balancing supply and demand in the stumpage market.

Nontimber Considerations in Sector Work

To a policymaker, the inference in figure 5a is that projected demands will exceed available supplies and policy actions will be needed to reduce the gap. Often the policy discussion is framed around reducing some shortfall of, say, 2.7 billion cubic feet in 2000. Implied, although seldom addressed, are the associated price changes expected, with failures, to fill the gap. Figure 5b illustrates a case where stumpage prices are used as the policy variable of interest. If, for example, continuation of recent timberland management practices is assumed, then stumpage prices are expected to increase (net of inflation) at 2.1 percent per year between 1990 and 2030. The policy issue is framed around the societal acceptance of that rate of price increase. If it is not acceptable, programs could be instituted to increase softwood tree planting and conversion of low-value hardwood stands on privately owned timberlands that would stabilize stumpage prices in the near decades (1990-2010) and, as the planted stands mature, eventually lower stumpage prices (see fig. 5b).

Both cases illustrate similar policy inferences but for different reasons. In the case of the gap analysis, perceived quantity shortfalls drive policy actions. In most countries, these shortfalls are not observable, as price changes cause market adjustments that offset supply shortfalls. In the equilibrium analysis, perceived price changes drive policy actions. The lack of policy actions usually is observable in the sense of undesirable price changes.

The frequent use of forest sector models in various policy applications imposes specific requirements on the modeling process. First, the models have to include the variables being considered or likely to be considered. Second, to be useful, models used in a policy context should help clarify the problem, outline the alternatives, and compare consequences. Third, declines in the quality of policy modeling must be guarded against as model size and complexity increase (Alien and others [1992] review these concerns).

Use of the land is an important variable in forest sector analysis because it establishes the base from which the supply of timber and the appropriate mix of nontimber forest outputs can be quantified. The forecast of present and future land uses also makes an intersectoral approach for the sector quite useful. In most developing countries, an important forest policy variable is the expansion of agricultural land. If policies are maintained that promote low-capital or extensive agriculture to free scarce resources for industrial development or other sectors, the forest area is bound to shrink rapidly. Forest land is cleared for cultivation because land often is the cheapest agricultural input. Forest land also is readily available because the traditional common property ownership of many forests is disintegrating with changes in traditional ways of life and giving way to an open access regime to land. Increasing insecurity of tenure favors the use of land for short-term benefits, which usually involve deforestation. Understandably, the modeling of land-use changes in such situations is difficult. Yet deforestation often is related to a single variable: population growth (Palo 1987). The FAO is now projecting global deforestation by using that simple population variable and validates it by relating these estimates to forest area measured through satellite imagery and ground checking.

In the United States, Alig (1992) developed a model that simultaneously projects shifts among major land uses, forest cover types, and ownership by using economic (GNP) and demographic (population) variables. Methods for projecting area changes are based on positive or normative approaches: land rent theory, expert opinion, and optimization models of econometric techniques have all been used to that effect. Expert opinion can be a useful approach in many countries facing rapid land-use change. Parks (1992) has applied the same type of approaches to questions about forest land-use changes in several areas in Southeast Asia.

In modeling the forestry sector, it is possible to integrate change in land use (an exogenous variable that can be influenced by policies external to the sector) and changes in timber management (a forestry policy variable) with the production of nontimber outputs, such as forage, wildlife (game and nongame), water yield, and fish production (Joyce and others 1992). But such a model is not easily formulated and then interpreted by the decisionmakers. The limitation of the modeling approach in integrating nontimber products is more obvious than for timber products, especially in developing countries where the database is minimal. It was felt by the participants at the Paris meeting, however, that the description and quantification of nontimber outputs of each forest type were pertinent information to be provided in the sectoral review.

Much of the discussion has not recognized the dual role that forests play in developing countries where they provide fuel, crude building materials, and timber input for wood-processing industries and for exports while at the same time providing protective resources. They help to maintain soil quality, stabilize hillsides, modulate climate, protect waterways and marine resources from accelerated siltation, and promote ecological diversity and wildlife conservation while providing many medicinal plants vital for health. Although the protective role of forests is very important, it is the productive role of forests that, in view of the need for economic development, seems to be valued the most in developing countries (Ehui and Hertel 1989, FAO 1967, Ross and Donovan 1986, Vincent and Binkley 1991).

There is an emerging view of forest-based economic development that is based less on the productive role and more on the protective role of forests. This is a view of development based on concepts of social forestry²⁶ and comes as a reaction to perceived failures of forestry projects coupled with severe deforestation and increasing rural poverty in developing countries. Westoby (1978) was one of the earliest proponents of this development approach when he recanted his support for forest-based industrialization²⁷ in favor of forestry activities that support agricultural productivity, rehabilitate land, and raise rural welfare. Both the World Bank and FAO also have come to observe the poor performance (in terms of benefits to the most

²⁶ "Agroforestry," "social forestry," "community forestry," and many other similar terms refer to the same thing and are used interchangeably in the literature (Gregersen and others 1985, Winterbottom 1990, World Bank 1978)

²⁷ Westoby (1962) was an early proponent of forest-based industrialization in developing countries endowed with large forest resources. This view of the role of forestry in developing countries influenced international institutions and financing agencies and led to a proliferation of forestry industrial projects in the Third World.

poor) of forest industries in developing countries and recommend, like Westoby, social forestry as a better way to promote sustainable forestry sector development in the Third World (Douglas 1983, Westoby 1978, World Bank 1978). The World Bank, FAO, and Westoby agree on their basic assessment of the major problem with forestry in poor countries; however, they differ significantly in their explanations of why the problem arises. For FAO, the problem is a planning problem deeply rooted not only in the poor technical and managerial capability of forest services in developing nations, but also in the failure to integrate rural communities in the planning process. The Bank views the forestry problem in developing countries as a financial misallocation problem whereby rural community development projects do not receive proper attention.

In Closing

Forestry sector analysis can be approached in different ways. Much of this discussion assumes that one way is to develop a single analytical framework, a model, for trying to incorporate most of the important variables affecting the sector in general (see Constantino 1992, Haynes and Adams 1992, Sidabutar and Chandrasekharan 1992). The other type of approach is to focus on one or two major issues such as fuelwood (Hyde and Seve 1992) or trade (Vincent 1992b). Partial models that tackle particular issues have to be linked at some point to the broad picture of the sector to allow decisionmakers to have an overall view of the sector situation. For practical purposes, small models are useful for addressing specific questions that can in turn help in making decisions. Yet most participants at the Paris meeting felt that a general approach, organizing and using all important information for the sector, is necessary to give a complete picture of the situation. The minimal approach (Harou 1992) provides general guidelines for a gap-type approach, such as defined earlier, but with enough flexibility to integrate more specific studies or models as required. Other models are available such as input-output (Essman and Pretzsch 1992) or national income accounting, which are particularly effective when an environmental account is introduced (Harou and Constantino 1992). Input-output and national account approaches are useful for policymakers because they focus on important policy variables such as employment, income, and demand in the sector. In addition, intersectoral issues are easily quantified by using these approaches. Although the biodiversity and carbon sequestration aspects of the forestry sector are very relevant, they seldom are addressed. Whatever the model used and general approach taken, Enabor and Umeh (1992) make it clear in their paper that such an exercise provides useful information for pressuring politicians to consider the forestry sector more carefully and, consequently, not to forget the sector in their annual budgetary allocation.

A changing physical and political landscape is requiring that management and investment initiatives in the forest sector consider ecological, institutional, legal, and sociological issues while reconciling concerns about efficiency, equity, and conservation. For international donor institutions and governments, analysis supporting such activities must incorporate these issues and be widely applicable in a developing country context. It is hoped that this paper will be a building block for research aimed at developing a framework for such analysis that will satisfy the changing needs of policymakers and planners.

Two points should be repeated in closing. First, the development of successful forest sector models seems to be enhanced if the modeling approach recognizes evolutionary behavior and its dependence on assumptions. Second, success depends, in part, on a decisionmaker serving as an advocate for modeling; this role of advocacy should not be diminished.

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Appendix 1 Example Gap and Equilibrium Models

Given

Current price (P_1)	\$0.28/cubic foot (ft^3)
Current quantity (q_1)	2106.1 million ft^3
Demand elasticity (e_d)	0.1446
Supply elasticity (e_s)	0.3081
Growth in demand	0 percent per year
Growth in supply	-0.5 percent per year

Question 1: What is the gap between consumption and production after 10 years?

	Current	+10 years
	<i>Million ft^3</i>	
Consumption	2106.1	2106.1
Production	2106.1	2003.1
Gap	—	103.0

Question 2: What is the expected rate of price increase necessary to balance supply and demand in 10 years?

The first step is to compute the supply and demand functions from the given data by using the equation,

$$q - q_1 = e q_1 / p_1 (p - p_1),$$

where q_i and p_i are the known (current) price and quantity pair and

e is the estimate of elasticity.

From the example data, the demand function is,

$$q = 2414.45 - 1101.24p.$$

The supply equation (computed using 2003.1 as q_i) is,

$$q = 1385.94 + 2233.45p.$$

The second step is to compute the new equilibrium price that balances supply and demand.

Current	+10 years
<i>Dollars/ft^3</i>	
\$0.28	\$0.31

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A satellite meeting of the 10th Forestry World Congress focused on the methods used for forest sector analysis and their applications in both developed and developing countries. The results of that meeting are summarized, and a general approach for forest sector modeling is proposed. The approach includes models derived from the existing literature and can be used as a structure for applying forest sector analysis in developing countries.

Keywords: Supply-demand relations, forest sector modeling, developing countries (forestry), Third World.

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