Timber Supply Model 96: A Global Timber Supply Model with a Pulpwood Component

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Abstract

This study involves an update of our earlier Timber Supply Model, which was fully developed in our book, *The Adequacy Of Global Timber Supply* by Sedjo and Lyon (1990), published by Resources for the Future. The new version, called Timber Supply Model 1996 (TSM96), uses an economic market supply/demand approach to project an intertemporal time path of the world's price and output level of industrial wood. As did the original TSM, the TSM96 provides projections of the time path of the equilibrium output levels of the several regions into which the world has been subdivided. A major new feature of TSM96 is that industrial wood, treated as homogeneous in the earlier study, has be subdivided into two different wood types -- pulpwood and solidwood. The supply of these two commodities is not independent. Rather they can be viewed as joint products in production.

The study develops a base-case projection, which gives the authors' best judgment of the timber situation likely to develop over the next few decades. Over that period total industrial wood production increases from about 1.7 billion cubic meters to 2.3 billion cubic meters, an increase of about 35 percent, while global pulpwood production increases from about 700 million cubic meters in 1995 to about 1.325 billion in 2045. Pulpwood price shows a fairly substantial increase throughout the first one-third of the period, a more modest increase over the second third, and a slight decline during the last third. Solidwood prices are almost the inverse of pulpwood, declining over the first third of the decade, increasing slightly over the next third and increasing in the last third of the decade. Over the whole of the 50-year period overall price increases are 30 percent for pulpwood and only about 8 percent for solidwood.

Keywords: timber models, markets, optimal control, projections, timber supply

JEL Classification No(s).: C62, Q21, Q23

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

BACKGROUND

This study involves an update of our earlier Timber Supply Model (TSM), which was fully developed in our book, *The Adequacy Of Global Timber Supply* by Sedjo and Lyon (1990), published by Resources for the Future. The new version, called Timber Supply Model 1996 (TSM96), uses an economic market supply/demand approach to project an intertemporal time path of the world's price and output level of industrial wood. As did the original TSM, the TSM96 provides projections of the time path of the equilibrium output levels of the several regions into which the world has been subdivided. A major feature of this study is the development of a number of scenarios in which a variety of alternative situations, assumptions and circumstances are examined.

A major addition to TSM96 is that industrial wood has been subdivided into two different wood types -- pulpwood and solidwood. The supply of these two commodities are not independent. Rather they can be viewed as joint products in production. Timber harvests may involve harvest for solidwood (e.g., sawlogs and peeler logs), for pulpwood (generally smaller logs that are used to produce pulp from which paper is made) or both. However, even

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when harvests involve only solidwood, the processing of logs into solidwood products (lumber and plywood) generates substantial wood residues, which are typically used as pulpwood.

The purpose of TSM96 is to function as a tool to assist in the task of assessing the condition and the adequacy of the long-term world timber supply. TSM96 is a useful vehicle for systematizing and formalizing the factors that affect long-term industrial wood supply as well as examining the nature of the forces and the interrelationships within and among supply regions. In addition, the projections can identify questionable implications of the assumptions of the model and/or assumptions of the specific conditions associated with the projections.

AN OVERVIEW OF THE MODEL

Unlike the earlier TSM, which views industrial wood as homogeneous, the TSM96 subdivides the industrial wood-supplying regions into their pulpwood and solidwood components. This subdivision allows for an analysis of both the pulpwood and solidwood components of industrial wood supply. However, because harvesting the resource generates a joint product, the pulpwood and solidwood markets are not independent but rather are highly interrelated. Thus a proper analysis requires that either component be examined as part of the whole.

Although some timber harvests involve solely the collection of a pulpwood resources, most harvests provide joint products in the form of solidwood and pulpwood. Even when all the logs harvested are involved in the production of solidwood products, e.g., lumber, substantial residues are generated that can and generally are used in producing pulpwood.[2]

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[2] With new products and engineered wood the distinction between solidwood and pulpwood is beginning to erode.

Thus the by-product of most solidwood production operations is pulpwood, which can be and is used as an input into pulp production. The TSM96 uses information about species, age and log size in the various forests to determine the mix between solidwood and pulpwood, thereby providing separate but interrelated projections of pulpwood and solidwood supply. Furthermore, the solidwood-pulpwood mix of the resources of a specific forest is also allowed to vary through a range, as a function of the relative solidwood and pulpwood price.[3]

A working hypothesis of this study is that, in the aggregate, timber production in the real world is experiencing a transition from the draw down of existing old growth stands to the utilization of second-growth and plantation-grown industrial wood. This transition is at different stages in the various regions of the globe. A basic question that the model is designed to address is that of determining the economically optimal transition from an old-growth forest to a regulated steady-state forest in a global setting.[4] This approach is in conflict with the common "growth/drain" approach to modeling forest harvest.

In the growth/drain approach supply is made a function of the stock of forest inventory. Because the growth-drain approach has no provision for the age distribution of the inventory, harvests are invariant to the age composition of the forest. While such approaches are useful when applied to even-aged regulated forests, such an approach can lead to serious errors when applied to a non even-aged situation. In fact, there is no mechanism for a transition from an old-

[3] This feature reflects the existence of some ability by producers to adjust the mix of solidwood and pulpwood inputs.

[4] Foresters are fond of the regulated or steady-state forest in which there is (a) an equal area of forest land for each age class; (b) a fixed rotation age; and (c) an age class for each year to rotation. Under this condition each year's harvest will be the same and steady-state production will be achieved.

growth to an even-aged regulated forest and no movement toward a long-term equilibrium. In a world in which the transition from old-growth to steady-state harvests is not completed, such an approach is not appropriate beyond the individual forest stand (see Sohngen and Sedjo 1996).

The TSM96 utilizes a control theory approach that introduces "initial conditions" and "laws of motion" for the forest system. "Control" variables are introduced to monitor and describe the changing "state" or condition of the forest. The initial conditions refer to conditions that obtain initially, such as the forest inventory by location, age group and land class. Since the initial conditions include old growth and various other non-regulated timber stands, the approach requires "laws-of-motion" rules that govern the system over time, that can address an initial stock that includes large volumes of old growth.

In the control theory approach, the changing age and volume conditions of the forest are constantly monitored and updated so that management decisions explicitly recognize the changing state of the forest. In this approach the laws-of-motion have young trees becoming older; and as older trees are harvested, either natural regeneration occurs on the site or investments in regeneration are made. Any investments, in turn, influence the rate of growth of the forest. The control variables, or choice variables, give the area harvested by age group and land class for each year. This, in turn, determines the rotation age by land class. Also control variables determine the investment in regeneration and the magnitude of regeneration input each year by land class.

An optimization procedure calculates the values of the control and state variables in the steady state. A solution algorithm then solves for the optimal values of the control variables in the transition between the initial conditions and the conditions of the steady state. The optimal control variable values generate an evolution of the state variables from their initial values to their steady-state values that identify the economically optimal time path of price and harvest between the initial conditions and the terminal steady state. The economically optimal time path is the one that maximizes the sum of consumer and producer surpluses in the transition between the initial conditions and the steady state.

Uses of Models

The ability of models to examine the implications of alternative assumptions and situations is one of their major strengths. A formal model allows the user to examine possible futures under various assumptions regarding relationships and events. Since the assumptions must be explicit, the model forces the analyst to define precisely the assumptions and to confront the implications of the assumptions. Fundamental deficiencies or logical inconsistencies in a model's structure and/or underlying assumptions, are reflected in the form of implausible projections. These types of results force the analyst to reconsider the structure and assumptions of both the model and the analyst's thinking.

For example, an important implication coming out of TSM96 is that it demonstrates that if pulpwood demand grows sufficiently more rapidly than the growth of overall industrial wood demand, a logical implication is that there must be an absolute decline in the production and consumption of solidwood, as pulpwood demand bids raw wood away from solidwood uses. This finding reveals the interrelationship of demand for pulpwood and demand for industrial wood. Since they draw in part from the same resource basket, they are not wholly independent. However, some analysts make the mistake of trying to assess the global pulpwood market without recognizing its relationship with total wood supply.

Rational Expectations

The model is a rational expectations[5] model in that the solution assumes that economic agents *on the average* correctly anticipate future conditions.[6] One implication of this formulation is that if future demand is going to increase substantially, economic agents adjust to the anticipate higher future prices by reducing harvests today to be able to increase harvests in the future. This behavior results in shifting harvests from the present to the future. Lower current harvests result in increased current prices, while increased future harvests decrease future prices. Similarly, the expectation of higher future prices will result in increased investments in regeneration today.

Factors Affecting Harvest Levels

In the TSM harvest levels can be affected by adjustments of six types:

1. the rate of draw down of old-growth inventories;
2. the number of forested land classes utilized for harvest;
3. the rotation length;
4. the level of regeneration inputs, which influence future harvest levels;
5. the rate of technological change in timber growing; and

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[5] Robert Lucas recently received the Nobel prize in economics for developing the rational expectations approach.

[6] Many timber models are not rational expectations models. For example, the US Forest Service's TAMM solves each period independently. In this model, economic agents are assumed to have no expectations of even the next year's price and harvest conditions.

6. the rate at which industrial plantations are added to the world's forest-producing regions.

The first three of these factors relate to the rate at which existing forests are harvested and are determined within the model (endogenously). They are affected by the current and future prices, as well as the interest rate. These can be viewed as short- or medium-term effects. The last three factors relate to the rate at which new sources of wood are made available or used more efficiently.

The fourth factor, investments in regeneration, is determined endogenously in the model. This activity influences future harvest levels. The fifth factor is dependent on the rate at which technological progress is incorporated into the forest's yield function and thereby effects timber growth. Its effect on timber growth enters the system via the regeneration component in the supply model. The sixth factor is the rate at which new industrial plantations are established. In the timber supply model the base case assumed that 200,000 ha of new plantation be established annually, beginning in year one for 30 years. This assumption is revised in TSM96. Finally, technological change can also enter TSM96 via the demand side by reducing the rate of increased demand for the raw wood resource.[7]

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[7] A host of technological innovations are wood saving and wood extending in that they allow intermediate and final products to be produced utilizing less wood, or lower quality wood, than previously. Examples include wood-saving pulping techniques and new types of engineered wood, such as oriented strand board (OSB). The effect of wood-saving technology is to reduce the wood requirements of various intermediate and final products using wood thereby lowering the rate of outward shift in the demand curve for industrial wood for a given rate of increase in the demand for the final product.

TSM96: SOME SPECIFICS

In this section we first discuss some specific features of the TSM96 and then move on to a detailed discussion of its application in examining pulpwood and solidwood supplies. The TSM96 subdivides the world into eight industrial wood supply regions, seven of which are formally modeled and called "responsive regions."[8] The "rest of the world" is lumped together as the eighth region and referred to as the "nonresponsive region." The harvests of the nonresponsive region are viewed as autonomous and determined independently of the usual economic considerations. This characterization is clearly only approximate in that some areas within the "nonresponsive" region do respond to market incentives, while some ownerships in the responsive region may not be fully responsive. The nonresponsive region includes (a) the former centrally planned economies, some of which have not yet developed efficient working markets for industrial wood, due in part to unresolved issues of land ownership and tenure, and (b) countries in of Europe that claim to have a tradition of harvest rotations that are longer than financially optimum. The characterization of this aggregate region as nonresponsive is probably an adequate overall approximation.

As in the earlier TSM, the seven responsive regions of TSM96 are further subdivided into a total of 22 timber land classes, each of which corresponds to a unique geographic area. The specific regions are:

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[8] The industrial wood sectors of the seven "responsive regions" are treated as being driven by market forces under competitive conditions. Although this is not completely correct, it is probably a good first approximation. Even where a large portion of the market is served by public forests, as was the case in the US before the 1990s and still, to a lesser extent, is the case today, the results can be viewed as approximating the market since the large private sector responds to price signals generated in part by the harvest levels of the public sector. Thus, the market Timber Supply Model can be applied.

Responsive Regions

Emerging Region[9] (1 land class)
US Pacific Northwest (4 land classes)
Canada, west (2 land classes)
Canada, east (4 land classes)
US South (8 land classes)
Nordic Region (2 land classes)
Asia-Pacific (1 land class)

Nonresponsive Region

Rest of the World

TSM96 incorporates physical and biological elements to provide what economists might call an underlying biological production function. Each of the 22 land classes in the model incorporates physical and biological information appropriate to the area and develops a production function. This includes information on land-class quality, location, accessibility, and area; growth and yield functions by dominant species and land class; existing inventories and their age distribution; suitability of timber for sawlogs or pulping;[10] and silvicultural responses to investment inputs. The amount of investment in forest regeneration and management is determined endogenously.[11] In some situations a land class may not be harvested since there is no mature timber or because the stumpage price does not justify

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[9] The Emerging Region is a composite consisting of a number of regions that are producing industrial wood from intensively managed exotic species tree plantations. These include countries such as Brazil, Chile, Indonesia, New Zealand, South Africa and Spain. Although the species, growth rates and rotations vary somewhat across regions, all these plantations have relatively rapid growth and short rotations.

[10] Suitability is determined largely by average log size (width) with large logs having a greater fraction of their total volume going to solidwood.

[11] See appendix N of *The Long-Term Adequacy of World Timber Supply* (Sedjo and Lyon, 1990).

harvesting this land class, given the harvest and transport costs and the alternative wood sources available.[12]

Technological change in tree growth is introduced into the model through genetic improvement that is imparted to improve growing stock introduced through artificial regeneration. When new high-yield seedlings are planted to regenerate the forest after harvesting, the yield function of the forest coming from that year's regeneration cohort is shifted upward, reflecting the superior growth of genetically improved stock. The increased yield associated with that age class is captured at harvest.[13] Since naturally regenerated forests do not incorporate genetic improvement, the yield function is shifted only for artificially regenerated forests.

Also, each land class has a unique set of costs including establishment, growing, harvesting, transport to a pulp mill and international transport costs. The industrial wood product is assumed to be processed in a local pulp mill and transported to the world market. Since the focus of this analysis is the resource, the mill costs are assumed to be identical across regions. The costs of transporting the processed product to the world market, which in part determine the timber's delivered value to the mill and the stumpage value, depend upon the region's location vis-à-vis the major world market. The world market price is the net price

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[12] This feature means that the timber base is allowed to expand and contract depending upon the endogenously determined price.

[13] We assume that technology is progressing at an initial rate of 0.5 percent annually decreasing linearly to zero in year 50. The rate is embodied in the current year's yield function and introduced through the regeneration input. If a forest is wholly naturally regenerated, no technology is introduced. If there is $500 of regeneration per ha, the entire 0.5 percent is captured by that year's age class. Regeneration between zero and $500 is prorated proportionally. See chapter 6 and appendix L of *The Long-Term Adequacy of World Timber Supply* (Sedjo and Lyon, 1990).

(fob) the pulpmill mill receives for the processed product. The world market is treated as consisting of three submarkets -- eastern North American, western and central Europe, and East Asia. Prices among these markets could differ, but not by more than transport costs, since arbitrage is assumed to limit the price differentials.

The level of output of the nonresponsive region is viewed as independent of market conditions. This aggregate region is assumed to continue its production over the 50-year period with the growth of annual output based upon historic trends. Its production is assumed initially to be expanding at 0.5 percent annually, falling linearly to zero at the end of the 50-year period. In the period 1985-1995, total world industrial wood production is divided roughly equally between the seven responsive regions and the nonresponsive region.

On the demand side, total world industrial wood demand first interacts with the known nonresponsive region supply to generate an excess or derived demand curve for the industrial wood of the responsive region. In the TSM96 base case, the total world industrial wood-demand function is initially assumed to be shifting out at 1.0 percent annually,[14] linearly declining to zero growth in year 50.[15] This, in turn, generates an initial rate of expansion of about 1.5 percent annually for the excess demand curve that is applied to the responsive region. The excess demand curve is then related to the supply conditions (production and cost

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[14] The rate of growth of world demand for industrial wood from 1970 to 1991 reported by the FAO was 1.0 percent. Also, no attempt is made in this model to forecast the business cycle and the projections should be interpreted as long-term trends.

[15] For tractability, the trends in the model converge to zero in year 50. Therefore the more useful projections occur in the early part of the period, roughly the first three decades.

functions) of the 22 land classes of the responsive regions to generate the individual and aggregate supply curve for the responsive regions.

MODEL MODIFICATIONS

As noted, the TSM96 is developed by modifying the original TSM. These modifications consist of two basic types. First, the conditions in the original TSM are updated to reflect 1995 conditions. Second, modifications and adjustments are made to provide for the estimation of separate supply functions for industrial wood and pulpwood. These modifications are first:

i. Changes in timber inventory base used in the original TSM to reflect the passage of time and harvests which have occurred during the intervening period between the completion of the original TSM several years ago and the current development of the TSM96. The initial timber inventories are adjusted to reflect the 10-year difference in the beginning conditions, i.e., the TSM's initial year was 1985 while that for the TSM96 was 1995.[16]

ii. An adjustment of the land base to reflect changes in the timber available for harvest that have occurred as the result of policy. The forest inventory bases in the Pacific Northwest and British Columbia have been reduced by one-third and 15 percent respectively.

iii. The initial conditions are adjusted to correct for the more rapid than anticipated establishment of plantations in the emerging region. Thus the area in industrial forest plantations and the vintage of the plantations are adjusted to reflect the higher establishment rates that occurred in the 1980s and early 1990s.[17]

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[16] The updating of inventories is achieved simply by running the model to the year desired and making some modest adjustments to provide crude compatibility with the results of the Wood Resource International (1995) report. In the control theory process the model keeps track of the decreases in inventories that result from harvesting as well as the increases in inventories due to growth, management and new plantations.

[17] The base case of the TSM assumed 200,000 ha established annually. The revised model increases this to an average of about 500,000 ha established annually through the late 1980s and early 1990s, which appears to be the best estimate of plantation establishment in recent years.

iv. An adjustment of other initial conditions of the model to reflect the 1995 situation were undertaken. For example, although a precise comparison of the initial year of the projections of the TSM96 with the actual pulpwood production in 1993 (Wood Resources International Ltd., 1995) is difficult because the regional breakdowns in the data are somewhat different and the 1993 data are not strictly comparable to our 1995 initial year, the initial harvests of the TSM96 are nevertheless reasonably comparable to those which were estimated by WRI for that period.

Table 1. World Pulpwood Production 1993 (million cubic meters)

Asia	38
Africa	11
Oceania	14
United States and Canada	355
Other, North America	1
South/Central America	39
Western Europe	119
Eastern Europe	9
Former Soviet Union	33
Total	619

Source: Wood Resources International Ltd. (1995), p. 8.

v. An increase in the base-case rate of plantation establishment for TSM96, reflecting increased actual establishment rates and our expectation of future rates of establishment.[18] In addition, the average yield rates of the plantation region were adjusted[19] so as to more accurately reflect average performance

[18] Our best estimates of current annual rates of industrial plantation establishment from nontraditional regions are 200,000 ha for South America, 150,000 ha for Southeast Asia including Indonesia, and about 150,000 ha for Oceania. In addition, China is undertaking tree planting at a substantial, but difficult to quantify rate, and other regions also have positive rates of plantation establishment. In the base case, we assume that plantations in nontraditional regions will be added at 600,000 ha per year declining gradually to zero in year 50.

[19] To accomplish this, the yield function of the emerging plantation region was reduced from an average of 20 cubic meters per ha per year to 17.5 cubic meters. This adjustment also reflects the well recognized phenomenon that the actual rates of growth in emerging region plantations, while high, are on the average somewhat lower than the better growth rates often cited. This reflects the fact that the cited growth rates are commonly taken from experimental plots which typically have better than average growth rates.

and to calibrate the initial base-case plantation harvest levels of the TSM96 with the information on pulpwood supplies in 1993 as provided by Wood Resources International Ltd.[20]

vi. Also, some modest changes were made in the harvesting costs for land class 7, the more inaccessible areas of western Canada. Specifically, the harvest cost for the land class were reduced from $19.00 to $13.00 per cubic meter and the domestic transport costs from $12.35 to $9.00 per cubic meter to be more reflective of the actual role this region plays in production.[21]

The second change was to make appropriate modifications and disaggregations in the TSM96 so as to provide for the production of two separate wood commodities -- industrial wood and pulpwood. Modifications of the original TSM were required on both (a) the demand side, and (b) the supply side.

Demand

The demand function for the TSM96 expands on the single output of the original TSM. Pulpwood demand is added to the model as a subset of industrial wood demand. Implicitly, the solidwood demand function is the residual of the difference between the industrial wood demand function less the pulpwood demand function.[22]

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[20] No attempt was made to precisely relate the 1995 figures of the TSM96 with the estimates for 1993 obtained by Wood Resource International (WRI). Beside the differences in the year, the figures reflect cyclical phenomena which is not intended to be captured in the TSM96.

[21] The location of major pulpmills in parts of northern Canada and the introduction of activities with scale economies, has reduced harvest and transport costs for many locations.

[22] The implication of this structure is that, for any given rate of growth of total industrial wood demand, the more rapid the growth rate of pulpwood demand, the less rapid the growth of solidwood demand. A result of this formulation is that for a sufficiently rapidly growing pulpwood demand, solidwood demand would need to be declining. This is perhaps not as unlikely a real world event as it may seem. For example, during the period 1900-1985 total industrial wood demand growth in the US was only 0.81 percent annually.

On the demand side, the initial rate of growth in the industrial wood demand function was maintained in 1995 at the 1.0 percent annual increase rate that was applied in the initial year of the TSM, 1985.[23]

Based on recent output levels, an initial pulpwood demand growth of 2.25 percent.[24] In all cases the growth of the demand function is linearly reduced to zero by the end of the period. Under these conditions, over the period, the pulpwood share of industrial wood demand is allowed to grow from about 35 percent in 1995 to about 60 percent in 2045. This changing share reflects the anticipated long-term increase of pulpwood in total industrial wood demand.

Since the pulpwood demand function is a component of the total industrial wood demand function, the more rapid growth of the pulpwood demand function implies a reduced demand function growth rate for solidwood. This implication shows up strongly as slow and/or negative solidwood growth in many of our projections.

Supply

The TSM96 views pulpwood supply as coming from two sources. These are: (a) timber harvests which are undertaken explicitly to generate pulpwood and (b) as by-

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[23] Data on world production of forest products is notoriously lagged in its compilation and release and was not available in late 1995, as this study was being undertaken. We assumed that industrial wood production for 1995 would be about 1.7 billion cubic meters. Recent estimates put the number at only about 1.5 billion cubic meters, reflecting the large decreases in harvests in the former Soviet Union and the relatively stagnated economies of Europe.

[24] Worldwide demand for pulpwood grew at an annual rate of 2.53 percent between 1964 and 1985. However, for the subperiod 1970-85, the worldwide growth rate was only 1.4 percent. The FAO world pulpwood growth reported for the most recent period, 1980-1991, was 1.8 percent annually.

products of industrial solidwood production in the form of sawmill residues. The timber resources of each of the 22 land classes are allocated between solidwood and pulpwood. The initial division is based on the nature of the forest, e.g., typical log size, species, usual rotation age. In principle, all solidwood can be converted to pulpwood, but not all pulpwood can be converted to solidwood. For each land class an initial solidwood/pulpwood mix is given based on the nature of the timber in a land class. The actual proportions are allowed to vary within a range on either side of the initial proportions depending upon the relative price of solidwood and pulpwood.[25]

With these modifications the TSM96 now has additional initial conditions. In addition to land area for each land class, inventory age and volume by age, and yield function by land class, it also has as part of the initial conditions the mix between pulpwood and solidwood, by land class, including provision for mill residues becoming pulpwood. Also, included is a substitution function whereby the mix between pulpwood and solidwood can change within some limits as a function of the relative prices of pulpwood and solidwood.

The Model Solution

The TSM96 is solved given the known initial conditions, which now include both initial total industrial wood demand and pulpwood demand levels, and the rates of change of these demand schedules over the total period. The model is then solved for the steady state[26]

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[25] From the initial sawnwood/pulpwood proportion, the amount of solidwood can increase a maximum of 5 percent. However, pulpwood can increase to consume the entire log. The initial (reference) proportions and those of the base case and the extreme high demand scenario are presented in Appendix B.

[26] The steady-state solution is that equilibrium to which the global industrial system adjusts after which it

solution of both outputs by land class and price. Next, one of the set of feasible time paths, e.g., that which traces the path from the initial conditions to the steady state, is identified. Finally, the optimal time path, which maximizes the sum of producers' and consumers' surplus, is identified from among the feasible paths.

In TSM96, pulpwood production is constrained to be equal or to be less than industrial wood production for each region. Solidwood production for each region is calculated as the difference between total industrial wood production and pulpwood production.

BASE CASE

The base-case presented in the TSM96 is an extension of the base case of the TSM as it appeared in our 1990 book, *The Long-Term Adequacy Of Global Timber Supply*. The base-case outcome is viewed by the authors as the most likely outcome, and it is against this case that the various scenarios are compared.

The assumptions used in the TSM96 for the base-case forecast are as follows:

1. World demand schedule[27] for industrial wood initially increases at an annual rate of 1.0 percent, with growth falling linearly in successive years to zero after fifty years.
2. World demand schedule for pulpwood initially increases at an annual rate of 2.25 percent, with growth falling linearly in successive years to zero after fifty years.

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provides a continuous given output over time.

[27] Being a market model where the price and quantities are determined by changes on both the supply and demand sides, the changes in production and consumption are generally different than the posited "changes in demand." Throughout this analysis the changes in demand refer to the changes or shifts in the demand function or schedule. The actual change in consumption and production will depend upon the price effects as well and the demand schedule shifts and will, in general, be a somewhat different percentage change than is the shift in the demand function.

3. The production of the nonresponsive region increases at a rate of 0.5 percent annually, falling linearly to zero after fifty years.
4. Biotechnological change is assumed to shift the yield functions upward to a maximum of 0.5 percent annually, falling linearly to zero after fifty years. Technological change is introduced via investments in regeneration. The rate for any specific land class is a function of the amount of regeneration investment varying between a maximum of 0.5 percent for regeneration investments of $500 per ha or more, falling to no technological change for zero investment in regeneration.
5. New forest plantations are established in the emerging region at a annual level of 600,000 ha, falling linearly to zero at year 50.
6. The dollar exchange rate is assumed to remain at the current level throughout the period of analysis.[28]

A Global Overview of the Base Case

Overall global pulpwood production (Figure 1.1) increases from about 700 million cubic meters in 1995 to about 1.325 billion in 2045.[29] Thus, there is almost a doubling of the production of pulpwood over the 50 year period. This magnitude of increase does appear to be reasonable over a five-decade period in the context of the expanding production from newly developed plantations, wood-saving technological change that is occurring in pulping [30], the increase in tree yields due to technology, and the worldwide increase in the use of recycled paper as a substitute for virgin fiber.

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[28] For a discussion of exchange rates used see Sedjo and Lyon, 1990, pp. 204 and 205.

[29] This increase is generated from both the responsive and nonresponsive regions. The responsive region increases come as the result of increases in technology, management and new plantations, as well as the addition of increased harvests from the marginal land classes that, in the TSM96, are induced into production by higher prices. The output from the nonresponsive region increases on the basis of historical trend and may well involve inclusion of the harvests from additional forest lands.

[30] Such as thermomechanical, chemi-thermomechanical and groundwood pulping techniques.

Additional insights into the nature of the base case and indeed the TSM96 can be gained by viewing pulpwood production as a part of the larger global industrial wood production. Figure 1.3 presents the total world industrial wood base case production by the eight regions for the 50-year period 1995-2045. Over that period total industrial wood production increases from about 1.7 billion cubic meters to 2.3 billion cubic meters, an increase of about 35 percent over a five-decade period; while, as noted in Figure 1.1, total pulpwood production essentially doubles over that period. This large shift in the composition of industrial wood production away from solidwood to pulpwood is necessary to accommodate the more rapidly rising demand for pulpwood.

The implication of the above is that, worldwide, total solidwood production must decline to allow such a large shift in the composition of production without even larger increases in total output. This, in fact, is projected on Figure 1.4 as total world solidwood production falls from almost 1.1 billion cubic meters in 1995 to about 980 million in 2045.

Finally, Figure 1.5 shows the real price trends of pulpwood and solidwood over the 50-year period. Pulpwood price shows a fairly substantial increase throughout the first one-third of the period, a more modest increase over the second third, and a slight decline during the last third. Solidwood prices are almost the inverse of pulpwood, declining over the first third of the decade, increasing slightly over the next third and increasing in the last third of the decade. Over the whole of the 50-year period, overall price increases are rather modest being about 30 percent for pulpwood and only about 8 percent for solidwood. The rise in pulpwood prices in the early period reflects the rapid rate at which pulpwood demand is expanding relative to solidwood. Thus, the pulpwood price must increase to attract wood from solidwood to pulpwood uses.[31]

The Regions

Figure 1.1 and Figure 1.2 present the base-case projections of total world pulpwood for the seven responsive regions and the aggregate nonresponsive region. Total world pulpwood production is projected to increase from about 700 billion cubic meters in 1995 to about 1.325 billion cubic meters in 2045. The contribution of the various regions can be read in greater detail from Figure 1.2, which focuses on the outputs of the seven responsive regions. The regions accounting for most of the present and projected incremental output are the emerging region followed by the US South. Production of the emerging region grows to almost twice that of the South after 50 years. In addition eastern Canada is a substantial pulpwood producer throughout the 50-year period, with some increase in the last one and one-half decades. The US Pacific Northwest and western Canada remain significant but modest producers of pulpwood. Although experiencing some fluctuations over time in production, the Nordic region continues as a major producer of pulpwood throughout the period. Throughout the entire period the Asia-Pacific region is only a very modest producer of pulpwood. The projections of the Asia-Pacific, however, do not incorporate the substantial expansions in

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[31] In the various scenarios examined only the base case and the integrated supply constrained have the very large difference between the rate of growth of pulpwood demand and that of total wood demand. This difference implies that solidwood demand is growing very slowly, if at all. In this case the price of pulpwood rapidly approaches that of solidwood as, through the early part of the period, the pulpwood market must bid wood away from solidwood market. A comparison of the prices of the base case and those of scenario 5 (Figure 6.5) is instructive.

pulpwood plantations and pulpmills that are envisaged in the plans of some Asia-Pacific countries.[32] Finally, a very significant portion of this shift occurs in the nonresponsive region.

The dominant producing regions in 1995 are the emerging region and the US South. The emerging region experiences roughly a doubling of pulpwood harvests, while the South increases production roughly by about one-third over the 50-year period in the base-case projection. In addition, the Nordic and eastern Canada regions maintain their production over the 50-year period, with eastern Canada showing a modest increase. The three regions with modest pulpwood production, the US Pacific Northwest, western Canada and the Asia-Pacific region, show only minimal harvest changes over the 50 years.

The base-case TSM96 projections show the seven responsive regions increasing their pulpwood production from about 560 million cubic meters in 1995 to 875 million cubic meters in 2045, or from roughly 80 percent of 1995 world total pulpwood production to about 66 percent of world projected pulpwood production in 2045. The extent of the decline in the portion of pulpwood provided by the seven responsive regions over the five-decade period, however, may be in part an anomaly of the unique situation existing in the early 1990s and built to some degree into the initial conditions of the TSM96. The 1993 data reflected the fact that sawnwood production in the former Soviet Union was well below its historical trend, due to the disruptions generated by the political changes that occurred in the early 1990s. Thus, the

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[32] For example, some early Indonesia plans anticipated having some 32 pulpmills by the year 2020, compared to the 14 mills currently in operation. However, our projections assume plantations being established at about the current rate of 125,000 annually and are captured in the output of the emerging region.

dramatic decline in the share of total pulpwood from the responsive regions reflects this abnormality of the early 1990s.

SCENARIOS

In this section we undertake a number of scenarios that explore the implications of hypothesized changes in the conditions applicable to the industrial wood industry. These include:

1. Decreasing Demand
2. High Demand (based on FAO forecasts)
3. Very High Demand
4. Integrated Supply Constraints with Base Case Demand
5. Integrated Supply Constraints with Low Demand
6. Very High Demand with High Plantation Establishment

Scenario 1: Decreasing Demand

This scenario examines the implications of an absolute decline in demand for pulpwood and industrial wood over the next 50 years.[33] The total industrial wood demand schedule is posited to *decline* at a rate of 1.0 percent in the initial year, then decline linearly moving to a zero percent demand change in year 50. The pulpwood demand schedule component is posited to decline at an initial rate of 1.5 percent linearly moving to a zero percent change in year 50.

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[33] In order to get the system to solve for output from the responsive regions, the production of the non-responsive region was decreased by 0.5 percent annually declining linearly to zero percent in year 50. In the absence of this adjustment, most of the production was generated by the nonresponsive region.

The projections from the decreasing demand scenario appear in Figures 2.1 though 2.5. World pulpwood production declines from about 620 million cubic meters in 1995 (year 0) to 570 million cubic meters in 2045 (year 50).[34] All of the responsive regions except the emerging region experience pulpwood output declines over the 50 years (Figure 2.2). Eastern and western Canada, as well as Asia-Pacific, produce essentially no pulpwood in year 50. The US South and the Nordic regions both produce significant, but reduced, volumes in year 50. The Pacific Northwest pulpwood production is modest throughout the period, but lower in year 50.

Total worldwide industrial wood production (Figure 2.3) also declines in this scenario, from about 1.7 billion cubic meters in 1995 to roughly 1.5 billion in 2045. Total solidwood production changes little over the 50-year period (Figure 2.4), rising from 320 million to 360 million cubic meters over the 50 years, with the highest production level, roughly 400 million, being reached after about 30 years.

The reduction in industrial wood and solidwood production is less than the reduction in the demand schedule since the consumption decline is mitigated by the fall in wood prices. Both solidwood and pulpwood prices decline throughout most of the period. Solidwood prices fall from an initial level of about $55 to $42 after 30 years terminating at about $44 in 2045. Pulpwood prices fall from $38 in year 0 to about $18 in year 50.

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[34] In a standard nature resource model, e.g., fisheries, a reduction in demand would result in a drawdown of the initial stock to the new lower equilibrium level. In the TSM, however, demand is decreasing through time, but supply is also decreasing as several (11) of the land classes fall out of production due to the low prices. Thus, the stock has been adjusted downward, largely through the reduction in price, which makes much of the original timber stock financially submarginal.

Scenario 2: High Demand (based on FAO forecasts)

This scenario examines the implications of a scenario which is loosely based on recent FAO forecasts. The FAO forecasts the demand of total industrial wood to increase by 1.8 percent annually and pulpwood to increase at a rate of 2.5 percent annually to the year 2010.[35] In this scenario the growth period is extended to 2020, with the growth of demand declining linearly to zero in the year 2045, or after 50 years.

The results are presented in Figures 3.1 through Figures 3.5. Figures 3.1 and 3.2 present the model's projections of world and region pulpwood production for the high demand scenario. In this case, 1995 pulpwood production is at 600 million cubic meters,[36] rising to 1.375 million cubic meters by 2045.

Although the pulpwood output total in 2045 is only about 50 million cubic meters above that of the base case,[37] overall industrial wood production approaches 2.6 billion cubic meters in 2045, about 300 million cubic meters above the output level of the base case. Figure 3.5 shows the behavior of relative prices. Both solidwood and pulpwood prices rise substantially throughout the 50-year period. Pulpwood prices almost double from the low $40 to the low $80. Solidwood prices more than double from about $60 to around $135.

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[35] For this scenario we interpret the FAO increase in demand to refer to the demand schedule, and thus the quantity actually demanded may be different from this due to the price effect.

[36] It will be noted that the various scenarios give different initial 1995 production figures. This reflects the different expectations regarding future prices. If future prices are high, this expectation is reflected in lower current harvest levels as some of the harvest is postponed into the future when prices will be higher.

[37] The modest increase in pulpwood output reflects the relatively smaller increase in pulpwood demand compared to the more rapid rate of overall demand. This is reflected in the decline of the pulpwood price relative to solidwood over the period.

Scenario 3: Very High Demand

This scenario posits a growth rate of the demand schedule twice that of the FAO scenario (scenario 2) above. In this case, the total industrial wood demand schedule will initially grow at 3.6 percent and pulpwood demand schedule at 5.0 percent to the year 2020. Thereafter, both will decline linearly to zero at the end of fifty years in year 2045.

The results are presented in Figures 4.1 through 4.5. In this scenario initial annual production of industrial wood and pulpwood is very low, about 1.1 million cubic meters and 320 million cubic meters respectively. This low production is due to the rational expectations in the model which causes initial harvests to be postponed in anticipation of higher future prices. Pulpwood production increases to a very high 2.2 billion cubic meters in year 50 and total world industrial wood production, Figure 4.3, increases to 2.9 billion cubic meters in year 50. The rate of growth of the pulpwood demand schedule outdistances that of solidwood so that total solidwood production (Figure 4.4) declines from 780 to about 750 million cubic meters over the period. Finally, prices of both solidwood and pulpwood rise substantially throughout the 50-year period. Solidwood price rises from about $80 to around $310, while pulpwood prices rise from $60 to $310.

Regionally, most of the responsive regions postpone both pulpwood and solidwood production in the first two decades thereby allowing outputs to increase substantially in decades three and four. In decade five output growth flattens. Again, the major pulpwood producers are the US South and the emerging region. However, all of the regions, including eastern Canada and the Nordic region increase output substantially over the 50-year period. Western Canada, the Asia-Pacific and the Pacific Northwest show the lowest pulpwood production throughout the period but still expand production during the later years when prices are high. Solidwood production by the responsive regions is modest since most of their production was consumed as pulpwood.

Scenario 4: Integrated Supply Constraints with Decreasing Demand

The objective of this scenario is to examine the effects on output and prices of a highly constrained wood production system. In this scenario, the following constraints will apply.

- 10 percent set-aside from all lands
- harvest costs increase by 20 percent
- no new plantation establishment
- no yield increases
- Eastern Canada has a ceiling harvest of 120 million cubic meters.
- US South has a ceiling harvest of 300 million cubic meters.

Scenario 4 applies the decreasing demand schedule conditions of scenario 1 to a highly constrained supply side. The combined effects severely limit wood production levels and also depress wood prices.

The demand growth in this scenario is the same as Scenario 1, Decreasing Demand. In this scenario total industrial wood demand is posited to decline at a rate of 1.0 percent in the initial year, linearly moving to zero percent demand change in year 50. Pulpwood demand is posited to decline at a rate of 1.5 percent in the initial years linearly moving to a zero percent demand change in year 50.

The results of this scenario, titled on the figures as the integrated constraint ("Integ Constr") scenario, appear in Figure 5.1 through Figure 5.5. World pulpwood production initially is at about 570 million cubic meters, but falls over the 50-year period to 420 million cubic meters. Regionally, production is essentially stable or falling slightly for each region. The exception is the emerging region in which the absence of new plantations and very modest investments in regeneration lead to a very sharp decline in pulpwood production. Overall world industrial wood production (Figure 5.3) also declines, falling from 1.6 billion in year 1 to about 1.25 in year 50. As with pulpwood, world solidwood experiences a substantial decline (Figure 5.4). Figure 5.5 presents the price projections and shows solidwood prices remaining essentially constant over the period at $58, while pulpwood prices decline from $45 to about $35.

Scenario 5: Integrated Supply Constraints with Base-Case Demand

The objective of this scenario is to examine the effects on output and prices of the same highly constrained wood production system as examined in Scenario 4 combined with the demand growth posited in the base case.

Scenario 5 applies the modestly expansive demand conditions of the base case to a highly constrained supply side. The combined effects of the series of supply-side constraints together with the modestly expansive demand conditions are to severely limit wood production levels even as demand continues to be expansive.

Figure 6.1 shows total global pulpwood expanding from 480 million cubic meters to 1.0 billion cubic meters at the end of 50 years. Under these conditions the emerging region and the US South are the major pulpwood supplying regions (Figure 6.2).

Output continues to be maintained from the emerging region due to the high prices which promote regeneration investment. In addition, the relatively high prices generate pulpwood output from all the regions except Asia-Pacific in the latter years.

World industrial wood (Figure 6.3) increases from 1.3 billion in year 0 to 1.65 billion in year 50, while solidwood (Figure 6.4) decreases modestly. Under the constrained supply conditions, prices for pulpwood rise from $60 to $80 over the period and for solidwood from $77 to $87 (Figure 6.5).

Scenario 6: Very High Demand with High Plantation Establishment

This scenario estimates the rate of plantation establishment that would need to be forthcoming to offset a posited very high rate of increase in the demand schedule. As such it combines the very high demand conditions of Scenario 3, with a very high level of plantation establishment. A trial-and-error method was used to determine the level of plantation establishment required to stabilize pulpwood prices. It was estimated in this analysis that an annual plantation establishment level in the order of 6.5 million hectares would be needed for the first 25 years, thereafter declining linearly to zero by year 50.

The results are reported in Figures 7.1 through 7.5. Total world pulpwood production increases dramatically from about 700 million cubic meters in year 0 to 4.3 billion in year 50. The dominant source of increase is the emerging region, which dominates the other regions. The US South, eastern Canada and the Nordic regions continue to be producers, with only small volumes coming from some of the other regions. Total world industrial wood (Figure

7.3) rises to almost 6.9 billion cubic meters and solidwood (Figure 7.4) to about 2.5 billion in year 50 under this scenario.

Finally, pulpwood prices, which have been kept relatively stable by the increase in plantations, rise slightly from $40 in the initial year to $53 in year 50, with the maximum price approaching $70 about year 40. Solidwood prices rise from $60 in the initial year to about $80 in year 50. Although not strictly constant, the prices are relatively stable, especially in light of the dramatic increases in production and consumption.

Table 2. Summary: Production and Prices for the Base Case and Scenarios

	Production Year 50 (Bn m3)		Prices ($/m3)	
Scenario	Pulpwood	Total Industrial	Pulpwood over 50 years	Solidwood over 50 years
Base Case	1325	2.3	31 - 40	52 - 57
Decreasing demand	0.570	0.930	38 - 18	55 - 44
High demand (FAO forecasts)	1.375	2.6	40 - 80	60 - 135
Very high demand	2.2	2.9	60 - 310	80 - 310
Integrated supply with decreasing demand	0.43	1.25	45 - 35	58 - 58
Integrated supply with base-case demand	1.0	1.65	60 - 80	77 - 87
High demand with high plantation establishments	4.3	6.9	40-53	60 - 80

RESULTS

The above scenarios show that very large differences in output and prices are associated with large differences in the rate of demand schedule growth and with large differences in the potential to produce and expand available supply. A summary of some aspects of the base case and various scenarios appears in Table 8.

The output levels of the base case suggest that modest increases in demand can probably be handled reasonably well by the existing market system of supply without requiring dramatically higher prices. However, as Scenario 5, the Integrated Supply Constraint scenario demonstrates, large constraints on supply are likely to result in both lower outputs and substantially higher prices. Finally, Scenario 6 suggests that dramatic increases in demand can, in principle, be managed without substantial price increases by increasing the rate of plantation establishment. However, for the demand increases posited (an order of magnitude increase to over 6 million ha annually), very large increases in plantation establishment would be required. Nevertheless, such an increase is probably possible, in principle, as large areas of land seem to be available in parts of the tropics and also in semi-tropical regions of South America and Asia (see Grainger 1988).

SOME LESSONS

Some of the outputs of this model, which are difficult to accept in the "real world" context, can better be viewed as lessons or implications as to the type of logic consistencies that are required.

Lesson 1: If pulpwood demand grows at a significantly higher rate for a long period of time, solidwood consumption will stagnate and ultimately decline. Upon reflection, this is intuitively obvious but easy to overlook. The model reinforces the logical implications of the underlying trends.

Lesson 2: If supply is constrained in some regions, the result will be increased harvest pressures on other regions and harvest levels beyond what might normally be considered realistic.

Lesson 3: In scenarios that involve substantially higher future demand, the initial harvest is likely to be substantially reduced in order to provide more harvest in the future, when prices are high.

In essence, harvests are shifted from periods of low demand to periods of high demand in order to maximize returns. This adjustment also tends to flatten the price trend lines.[38]

DISCUSSION BY REGION

US South

The US South is a major industrial wood producer, including importantly pulpwood. The South produces both conifer and hardwood pulpwood from plantations, managed natural regenerated forests and unmanaged naturally regenerated forests. The capacity for increased future harvests comes from more intensive management and increased harvests from the surplus of hardwood timber, the utilization of lower quality and less accessible forests, as well as the possibility of increased forest from croplands that revert or are converted to forestry.

The base-case projections show that the US South is the major pulpwood producer today, at the beginning of the 50 year period, and the projections indicate that the US South will continue to be an important and an expanding producer of pulpwood. This projected performance is consistent with the large areas of available land, good tree growing conditions including accessible terrain, an accessible and well developed transport infrastructure, and the large ongoing investments in tree growing that are being made and have been made over the past three decades. The South is also in a strong position to shift production between pulpwood and solidwood since, by extending the rotations 5-10 years, many pulpwood stands

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[38] This outcome is a result of using a rational expectation approach. However, it is clear that investors do consider future markets and expected prices when undertaking forestry investments.

can be converted into solidwood. Similarly, by reducing rotation lengths, more wood can be shifted into pulpwood.

The scenario analysis indicates that the South will be a major producer of pulpwood under almost all of the proposed scenarios. However, a large increase in emerging region plantations would have a dampening impact on the expansion of the South's production, as shown in Scenario 6. The lower prices associated with high plantation production would discourage investment and production in the South.

US Pacific Northwest

The original projections of the TSM reported in the Sedjo and Lyon book of 1990 anticipated a major timber production role for the PNW. However, policy changes that involved large reductions in harvests from public lands were captured in the modified reassessment undertaken in 1994 (Sedjo et al.). In that assessment adjustments were made in harvestable inventories in the PNW to account for the public lands set-asides. The TSM96 incorporates those 1994 changes in the TSM. Thus, pulpwood production in the PNW is expected to be relatively modest in the future due to the US policy which has severely restricted timber harvests from public lands, especially in the PNW. The results of the scenario analysis are generally consistent with this outlook, except for the extreme scenarios.

Pulpwood production in the PNW has been largely the result of residues that are created in the sawmilling process and reduced harvests, other things equal, imply reduced residues for pulpwood production. In the future these residues are expected to be supplemented by thinnings. However, the scenario analysis indicates that pulpwood production falls when pulpwood prices are low relative to solidwood as in the high plantation and low demand scenarios. This outcome reflects, in part, the region's ability to modify its sawmilling technique to produce more solidwood and less pulpwood.

Canada, west

Most of the pulpwood in western Canada comes from harvests of original forests. Along the coast the trees are relatively large. However, in the interior regions the trees are smaller and, in the northern areas, are useful largely only for pulpwood.

In the future, pulpwood production in the Canadian west is projected to be modest, in part due to the proposed reduction in harvests in British Columbia. As with the policy changes in the US PNW, the changes in BC policy were incorporated into the 1994 TSM model as a reduction in accessible timber. These modifications are also used in the development of the TSM96. However, there is likely to be some offsetting of the reduction in BC by increased harvests in other western provinces, such as Alberta.[39]

In our scenarios the role of western Canada as a pulpwood producer on a world scale is always modest. Under decreasing demand conditions pulpwood output may fall to very small, almost negligible, levels.

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[39] Overall, the modeling of western Canada and its contribution to total industrial wood production appear to be somewhat deficient with the industrial wood projections, especially of solidwood being too small. Future revisions of model will look to improving the modeling of this region.

Canada, east

As with western Canada, most pulpwood in eastern Canada comes from harvests of original old growth forests. The resource base involves vast tracts of native species. The trees are relatively small, and a large portion are mainly suitable for pulpwood.

Pulpwood production in the Canadian east is significant in the base case. Under most situations of expanding demand and higher prices, the role of eastern Canada as a pulp producer continues to be substantial. However, pulpwood production in eastern Canada is quite sensitive to pulpwood prices. Under conditions of falling prices, as in the decreasing demand scenario, the role of the Canadian east as a pulpwood producer can decline greatly.

Emerging Region

The emerging region consists of a host of countries that have not traditionally been major industrial wood producers. The emerging region's countries tend to be located in the tropics or semi-tropics, utilize non-indigenous species in a plantation mode, and have short-rotation, fast tree-growing conditions. These countries include Australia, New Zealand, Chile, Brazil, Spain, Portugal, South Africa, Indonesia, Malaysia, Thailand, Venezuela, Uruguay, and others. The focus on short rotations and fast growth suggests that the output of this region will be predominantly in pulpwood rather than solidwood.

The emerging region is a substantial producer of pulpwood today, with much of the growth coming within the last 15 years (Sedjo 1995). Over that period this region has increased its share of exports of pulp from 7 to 20 percent of the world export market. During this time the total market expanded by 43 percent.

The base case projects substantial production increases over the next five decades, essentially doubling its total pulpwood production. However, the scenarios show that this expansion could be substantially greater than projected in our base case if plantation establishment proceeded at a more rapid rate than assumed. In Scenario 6 the rate of plantation establishment was increased by a factor of 10 over the base case in the face of a very rapid growth in demand for industrial wood and pulpwood. In this scenario the output of the emerging region dominates world production.

Nordic Region

The Nordic region consists of Finland, Sweden and Norway, with the first two being large producers of pulpwood. The majority of the pulpwood harvested in the Nordic region is conifer from managed naturally regenerated stands, with lesser amounts from managed plantation forests (WRI 1995). Finland and Sweden supplement their domestic production of pulpwood with significant additions from imports. Included among the major foreign suppliers are Russia, Estonia and other countries of the former Soviet Union.

The Nordic region is a significant producer of pulpwood and our projections indicate that this will continue to be the case under all of the scenarios. Our projections indicate that Nordic production is relatively insensitive to the various scenario conditions, unless they are extreme. Under most scenarios Nordic pulpwood production is significant throughout the 50-year period under examination.

Asia-Pacific

The Asia-Pacific is only a very modest producer of pulpwood, currently less than 5 million cubic meters, and our projections see this situation continuing. The pulpwood source today consists of some plantation wood but mostly mixed tropical hardwood species. Our projections of the Asia-Pacific in the TSM and the TSM96 are based almost exclusively on harvests from the native forest and do not assume that large areas of new plantations will be established nor that there will be large increases in the use of mixed tropic timber pulpwood.

However, it should be noted that Indonesia does have very ambitious plans for the future creation of some 32 pulpmills by 2020. However, in our analysis the plantations that would be required to provide the pulpwood feed stock for these mills are incorporated in the emerging region.

Rest of the World

The "rest of the world" consists of all pulpwood producers not covered by the seven responsive regions and includes most of Europe (except the Nordic countries), the former Soviet Union, China, Japan and other major producers. Substantial changes have occurred in some of these regions since the development of the TSM, especially in eastern Europe and the former Soviet Union. In the former Soviet Union, for example, industrial wood harvests are reported to have declined as much as 50 percent during the earlier part of the 1990s, although some recovery has subsequently taken place.

Overall, our base-case projections have the rest of the world pulpwood production being about 20 percent of the total in 1995 rising to about 33 percent in 2045. The rise in the share of the rest of the world is attributed to the resurgence of pulpwood production over the period by the former Soviet Union, especially Russia.[40]

SUMMARY AND CONCLUSIONS

The TSM96 provides projections of the time path of the equilibrium output levels for the world and for the several regions into which the world has been subdivided. A major new feature of TSM96 over the earlier timber supply model is that industrial wood, treated as homogeneous in the earlier study, has be subdivided into two difference wood types -- pulpwood and solidwood. The supply of these two commodities is viewed as joint products in production.

The study develops a base-case projection, which gives the authors' best judgment of the timber situation likely to develop over the next few decades. Over that period total industrial wood production increases from about 1.7 billion cubic meters in 1995 to 2.3 billion cubic meters 50 years later, an increase of about 35 percent. Global pulpwood production increases from about 700 million cubic meters in 1995 to about 1.325 billion in 2045. Prices show a modest increase over the entire period but with changing sub-trends. Solidwood prices decline over the first third of the decade, increase slightly over the next third with the rate of increase increasing further in the last third of the decade. Pulpwood prices were approximately the inverse. Over the whole of the 50-year period, overall price increases are 30 percent for pulpwood and only about 8 percent for solidwood.

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[40] If future pulpwood demand increases more rapidly than solidwood demand, we would expect that most if not all regions would increase their relative production of pulpwood.

Figures are available from the authors
and from Office of External Affairs,
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