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AN ANALYSIS OF PROPOSED DOMESTIC CLIMATE WARMING MITIGATION PROGRAM IMPACTS ON INTERNATIONAL FOREST PRODUCTS MARKETS

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Any opinions, findings, conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the view of the agencies listed above.

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Executive Summary

The possibility of global warming within the next several decades has prompted the US Environmental Protection Agency to examine climatic change mitigation options within the forest sector. Among several options, an expansion in the forest land base and recycling are viewed as two potential programs that will increase the storage of carbon in biomass form.

Current restrictions on timber harvest on public forests in the Pacific Northwest impact the forest economy regionally, nationally and internationally. Any programs directed at climate change mitigation will need to address the changes the US forest sector is currently undergoing.

The present study analyzes the impacts of planting and recycling programs on the global forest sector using an economic model of world forest products markets. The CINTRAFOR Global Trade Model (CGTM) is employed to assess the impacts on prices, production, consumption and trade of forest products of increased land area plantings and recycling programs in the US. The results of a recent analysis on the impacts of timber supply reductions in the Pacific Northwest and their implications for climate change mitigation are also discussed in this report.

Two major conclusions are drawn from the study.

1) The impacts from an expanded forest land base on US forest products trade are felt mostly in Canada--the major exporter of lumber to the US--since public planting program funding is directed largely towards the southern US states where the majority of the productive marginal crop and pasture lands exists. A larger forest land base expands the production of forest products in the US South by lowering log costs. This allows the region to substitute southern forest products for Canadian forest products in northern US markets. As a result, lumber prices are also lower for US consumers.

   The impacts from tree planting programs on the forest land base in the US North and US West regions are relatively small, where fewer acres of potentially program-acceptable crop and pasture lands exist. There is no perceivable impact on US forest products trade with countries around the Pacific Rim. There is no perceivable impact on US trade with European markets.

2) Impacts from the recycling program are distributed across all US regions. The largest impacts, however, occur in the US South. Again, because of the trading position of Canada with respect to the US, the recycling program impacts the Canadian forest sector. The recycling program allows greater harvests of sawtimber in the South due to the decrease in pulpwood demand.

These two conclusions are sensitive to assumptions regarding the projected level of Canadian log harvest, particularly in British Columbia. Because of large inventories of accessible timber, harvests from the coastal and interior regions of British Columbia may expand during the 50 year period from 1990 to 2040, according to model projections. The harvest expansion produces a downward pressure on lumber prices in the US, a major consumer of Canadian lumber. As a result real lumber price projections show only modest growth in the US after 2000.

There is growing evidence that the projected allowable cuts for Canada as forecast by the model are too optimistic. When Canadian harvests are constrained to decline slightly over the next ten years, additional timber production occurs in the US South in the base scenario. However, the US South offsets only 18% of the Canadian reduction. The reduction in Canadian harvest levels results in a permanent shut down of Canadian mill capacity, since log imports would not offset the decline in log production in Canada. Mill processing capacity expands in the US South to offset previously-imported Canadian lumber.

Timberland withdrawal from the western US forest land base adds additional harvesting pressure in the US South. A 33% reduction in harvest levels in the western US and Canada promotes greater harvests from regions around the globe. Since the harvest to offset the decline in timber production comes from less productive lands, larger areas are harvested in other regions to meet a lower timber demand. Timber demand declines 38% of the total reduction in harvests. The 38% reduction implies a decline of over 11 million cubic meters in mill processing capacity in the western US and Canadian regions.

Planting program impacts will occur after much of the current restructuring in the forest sector takes place. Planting programs may help to alleviate the supply pressures for the US southern regions in the future. However, only a small portion of the expanded inventory will enter the timber markets. The results suggest that carbon storage may increase as land enrollment programs expand. However, land management may decline if these areas do not enter the timber market. The implications for carbon storage in the long run are unclear.

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Introduction

This report presents the results of an analysis of the impacts on international forest products markets of potential global warming mitigation policies initiated in the US. It is the result of an effort by CINTRAFOR and the US EPA to analyze the economic impacts of climate change mitigation programs on the global forest economy.

Trade is an important activity in the US forest sector and globally. In 1990 global production in forest products amounted to over 1 billion cubic meters of sawtimber, with roughly one half of that producing sawnwood and plywood (FAO 1993). Log trade amounted to roughly seven percent of the total sawtimber production. Trade of sawnwood and plywood reached 23% of the total sawtimber production.

The US is a significant trader in forest products. It imports a great deal of its consumption of lumber, mainly from Canada, and exports both logs and finished products to other regions. Within the US, the Pacific Northwest is an important exporter in the Pacific Rim markets, producing an excess to its consumption needs. Whereas Canada and the US South provide significant amounts of finished products to the US North, the Pacific Northwest provides both logs and finished products to the Pacific Rim countries as well as to the US North.

It is through these trade linkages that one would expect to see effects of forest policies implemented in the US on trading patterns. Using an econometric model of the global forest sector, the study measures the impacts of unilateral global warming mitigation policies initiated in the US on international forest products markets.

The study examines two policy options:

(1) those which will promote an expansion of forest lands such as the conversion of agricultural lands to forests; and

(2) a policy to increase recycling content of pulp and paper products;

While the withdrawal of federal lands from timber production in the US West is no longer an option, it has important implications for tree planting and recycling programs. As such it will also be discussed in this report.

Programs to utilize marginal agricultural lands better enroll land areas into forest uses and capture the benefits associated with greater carbon storage. Increasing forest land area will produce initial gains to carbon storage through an increase in carbon sequestration. As carbon accumulates in biomass, the expanded forest area will act as a carbon store, retaining carbon in biomass rather than allowing it to accumulate in the atmosphere. An expansion of timber area, however, may also increase timber supply in the future, possibly deflating timber prices and affecting regional and international markets through trade linkages.

A larger future timber supply in the US will also produce wealth transfers when the costs of producing the timber supply are not borne by the owner and when regional differences in land enrollment exist. Timber producers will see the value of their timber fall as timber supply expands. While timber resource owners lose value, timber processors gain welfare as log costs decline with greater timber availability.

Wealth losses to timber owners are important because, as a negative feedback on forest management activities and land holdings, they indicate a potential divestment of management by timber producers. Hence, negative wealth transfers to timber owners may reduce forest area and carbon stored in forestry land uses in the long run.

Reduced area of public lands available for timber production in the forest sector must be considered when evaluating land enrollment programs. While the current option to reduce public land base for timber production does not have the specific intention of maintaining stores of carbon, it will affect carbon sequestration and storage. Timber preserves will act to retain carbon already in biomass form. However, withdrawal of forest areas from active management may lead to higher risks for these carbon stores to be lost through natural catastrophes (Kershaw, *et al.*, 1993).

Recycling programs reduce some environmental impacts through waste reduction (*i.e.*, those associated with landfill usage). Recycling impacts carbon accounts through timber demand. Higher recycling rates will lower the demand for virgin pulp fibers (and reduce landfill usage). The lower fiber demand reduces the timber requirements for pulpwood. It may also impact sawtimber availability by reducing the competition between sawlogs and pulpwood logs. A reduction in the demand for wood chips by the paper and paperboard industry will also impact the reconstituted panel industry, since paper and paperboard products also compete with reconstituted panels for wood chips.

The conservation reserve program impacts the forest products industry by directly affecting the location and amount of future supply of timber. Additional acres are added to the timber land base when marginal agricultural lands are converted to forest: a long-term increase in timber supply. However, the timber land set-aside programs implemented by the federal government has a larger, more immediate effect on log markets. The short-term impacts from federal timber set-aside programs will likely have greater impacts on international trade since greater source substitution will likely take place, given the short-run nature of the impacts, the fixed nature of production capital, and the large lag times associated with capacity adjustments. Recycling programs impact the resource base indirectly through changes in the derived demand for timber.

The objective of this study is to estimate the impacts of the planting and recycling programs on international trade. The impacts of these programs on the domestic forest sector have recently been evaluated by Haynes, Alig and Moore (1992) and Winnett, *et al.*, (1993) using the US Forest Service TAMM/ATLAS model. In the following section the study methods are described. Key results for the base case are presented and discussed. The next section presents the results for the tree planting and recycling programs. A final section discusses them.

Methods

The study utilizes the CINTRAFOR Global Trade Model (CGTM) to analyze the trade implications of the US domestic programs of global climate warming mitigation. A short description of the model is provided in Appendix 1 for those readers interested in the model. As a first step in the analysis, data for the coniferous sector in the model was updated to 1990. Also, in order to examine the long-term implications associated with expanding inventories, the model's forecasts have been extended to the year 2040.

For timber inventory projections, the study has utilized PC-ATLAS (Mills and Kincaid, 1992). The study developed a simple linkage between PC-ATLAS and CGTM: CGTM provides decadal harvest estimates to PC-ATLAS; PC-ATLAS in turn provides decadal growth estimates to update CGTM inventory for the US. The US South is an exception; for this region 5-year periods were utilized.

Haynes, Alig and Moore (1992) provides data on the tree planting programs analyzed in this study. Since these programs are the same as those analyzed by Haynes, Alig and Moore, we do not describe them here. The study utilizes the management and inventory data the authors developed as input data for PC-ATLAS. Harvest input data are provided by CGTM analyses. The four tree planting programs analyzed were: Moulton and Richards at $110 million and $220 million funding levels; and Parks and Hardie at $110 and $220 million funding levels.

An analysis of timber harvest reductions was recently completed by Perez-Garcia (1993). These results will also be discussed, since federal timber lands were a major supplier of timber to the western states.

The recycling program analysis was implemented by adjusting pulpwood requirements downward by 45% by 1995. The pulpwood requirements were then held constant for all US regions to 2040. In addition to the above analysis, we have examined the effects of increased recycling with forest planting under the Moulton and Richards $110 million funding scenario.

A Base Case for the Global Forest Sector

A base case to project the development of the global forest sector requires a complex set of assumptions regarding the growth of the demand and production sectors, forest inventories and trade flows for the global forest sector. A description of these assumptions is provided in

Appendix 2. The base case is used to measure the impacts from planting and recycling programs by provideing a reference point which places the study results in perspective.

Key points in the base case results are:

Over the next fifty years (1990-2040) total log production from both public and private lands in the western US region is projected to fall from 53 to 32.5 million cubic meters (MMm3), mostly occurring in the public sector. The western interior region (Rocky Mountain region) is expected to decline in log production from 31 to 25 MMm3, also largely as a result of reduced public timber harvests.

The southern US region is expected to increase its harvest levels throughout the forecast period, reaching 117 MMm3 by 2030 and dropping slightly to 116 MMm3 by 2040. These production trends are illustrated in Figure 1.

Overall, model projections indicate that the US will expand the production of sawlogs by 3% over the fifty-year forecast period. The share of regional production shifts southward, however as timber harvest from the public sector declines and log prices in the western region increase. The western US share of softwood sawtimber production declines from 52% to 39%. The southern share increases from 43% to 55%.

Price forecasts for the southern US show sawlog prices rising continually throughout the forecast period. The majority of the price increase occurs in the first decade at about a 3% per year rate. Prices grow gradually thereafter at less than one percent annually (Figure 2).

The shortage of logs caused by federal timber land withdrawal causes the projected delivered sawlog price to increase in the western region. Delivered wood costs increase 11% by 2015, while log exports from the region continue to meet Pacific Rim demand. Unlike other US regions, however, log prices in the Pacific Northwest region's Westside are influenced by prices in the international Pacific Rim markets. Price-equalizing pressures from other regions constrain price growth of logs in the western US region. Figure 3 depicts the equilibrium prices for logs in the Pacific Rim countries.

The shortfall in export logs is caused by diversion to the domestic market (Perez-Garcia, *et al.*, 1994). The shortfall is met by a reduction in the demand for logs--mainly in Japan--and greater log exports from other regions in the Pacific Rim markets. Net of Japan's projected decrease in log import demand, log exports increase due to growth in Chinese markets. However, most of the growth in log exports occurs in Chile and New Zealand, as is illustrated in Figure 4. The rapid decline in log exports in Chile is due to increased domestic demand (reduced supply from a constrained allowable cut) and the decline in import demand, principally from China. Under these set of assumptions, Chile begins to export lumber to Pacific

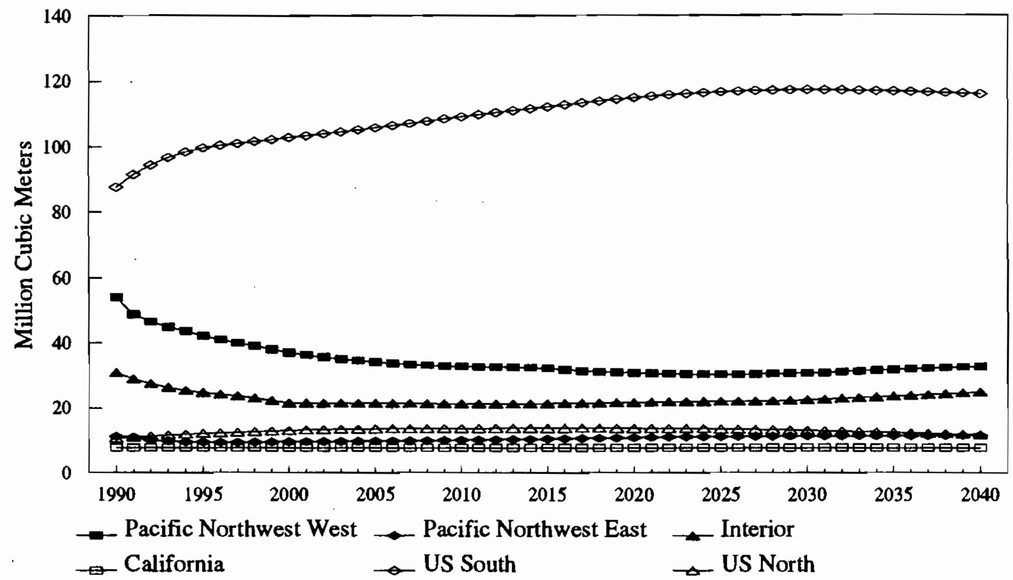

Figure 1: Projected harvest level of softwood sawtimber from US regions wtihout canadian restrictions of timber harvests.

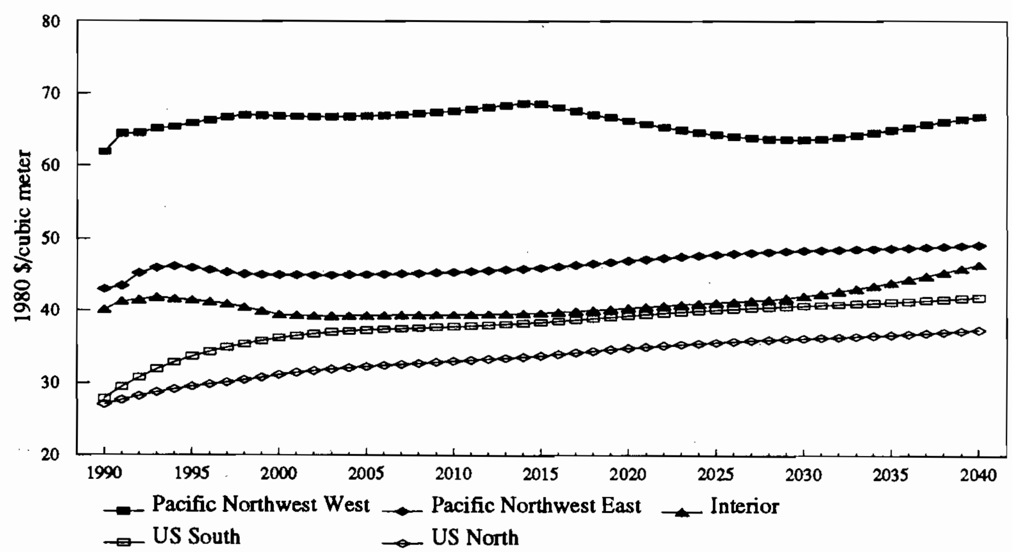

Figure 2: Projected delivered log prices for softwood sawtimber under base case conditions without canadian restrictions of timber harvest

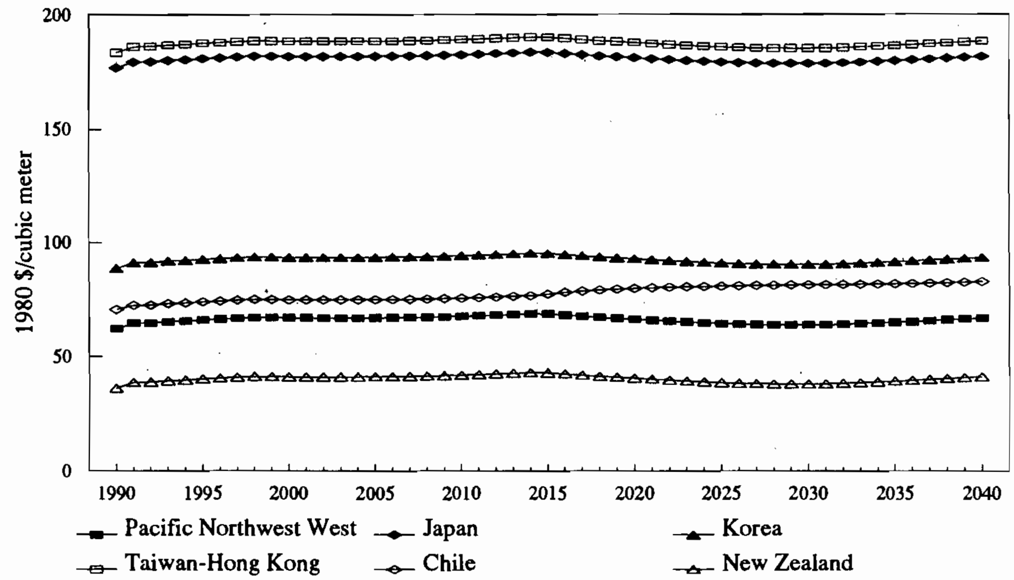

Figure 3: Projected delivered log prices for the Pacific Rim countries wtihout canadian restrictions of timber harvests.

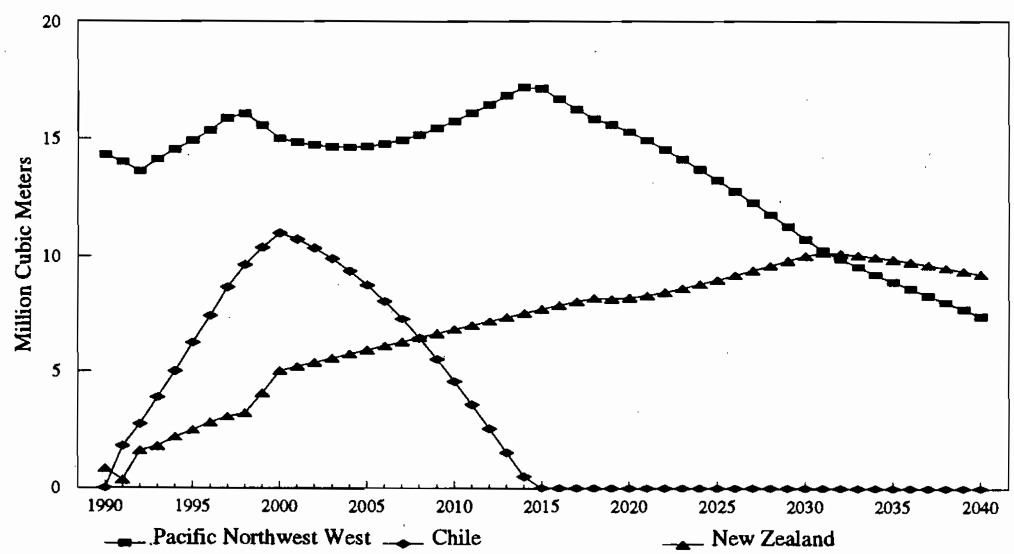

Figure 4: Projected softwood log exports under base case conditions without canadian restrictions of timber harvest

Rim markets. Higher domestic demand for logs and more logs from New Zealand in the Pacific Rim markets account for the projected decline in log exports from the Pacific Northwest region after 2015.

Canadian log production and softwood lumber market share is projected to grow when Canadian timber supply is not restricted. Figure 5 provides the projected softwood sawtimber production in the three Canadian regions. However, recently announced reductions in allowable cuts for Canada imply that projected increases may not materialize. If Canada were to increase its softwood sawtimber production, its share in the US lumber market would likely increase. Figure 6 illustrates the projected shares of US and Canadian production and consumption of softwood lumber. With relatively flat Canadian consumption, the model forecasts a greater level of exports of lumber into US markets as Canada increases its production of softwood timber. US production of softwood lumber is projected to decrease by 13% by 2000, due largely to the reduction in timber harvest in the US West region (and continued log exports to Pacific Rim countries).

With the assumption that Canadian mills will be able to continue their purchase of sawtimber as in the past, price projections for softwood lumber increase slightly for the various North American lumber markets. These price trends are illustrated in Figure 7. The price projections are impacted by the assumption of an unrestricted Canadian harvest, however. The following section describes the results of an analysis that considers the impacts from reduced timber harvests in the western US and Canada.

Reduced Federal Timber Supplies and Canadian Harvests

A recent analysis by Perez-Garcia (1993) presents results of a 33 million cubic meter reduction in timber harvest from the western US and British Columbia. The study suggests that timber resource constraints are becoming more important for North American and Pacific Rim forest sectors. A reduction in Canadian harvests accentuates the already low supply of timber from the western region of the US. This impact is reflected in the additional price projection growth observed for the western region. By 1995, prices in the Pacific Northwest reach levels observed by 2015 under the base case.

The cumulative impact of a 33 million cubic meter supply reduction--while only 4.5% of the global supply--is significant. It produces observable responses from other regions to offset the decline in harvests including a 16% redirection of trade flows. Reduced timber production is redistributed among major competitors around the globe. Major gains are made by higher-cost forest producers as log prices allow marginal producers to expand their production. Reduction in product supply is substantial, leading to a 30% reduction in product demand by 1995 as a result of higher prices. While this analysis does not directly address the impacts of demand reduction on non-wood product consumption, one can expect a higher use of energy-intensive non-wood substitutes to replace the loss in wood product demand.

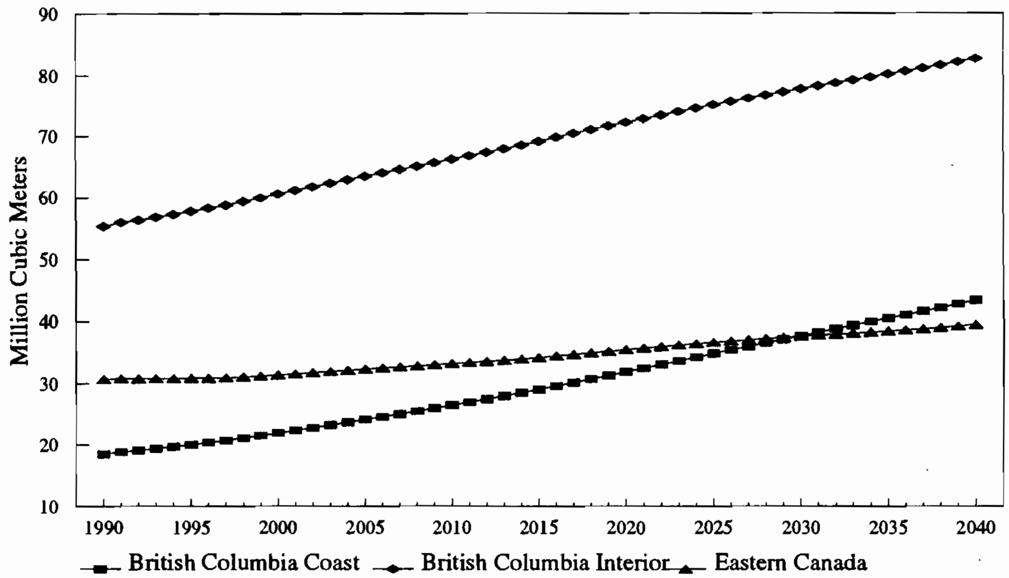

Figure 5: Projected softwood sawlog production wtihout canadian restrictions of timber harvests.

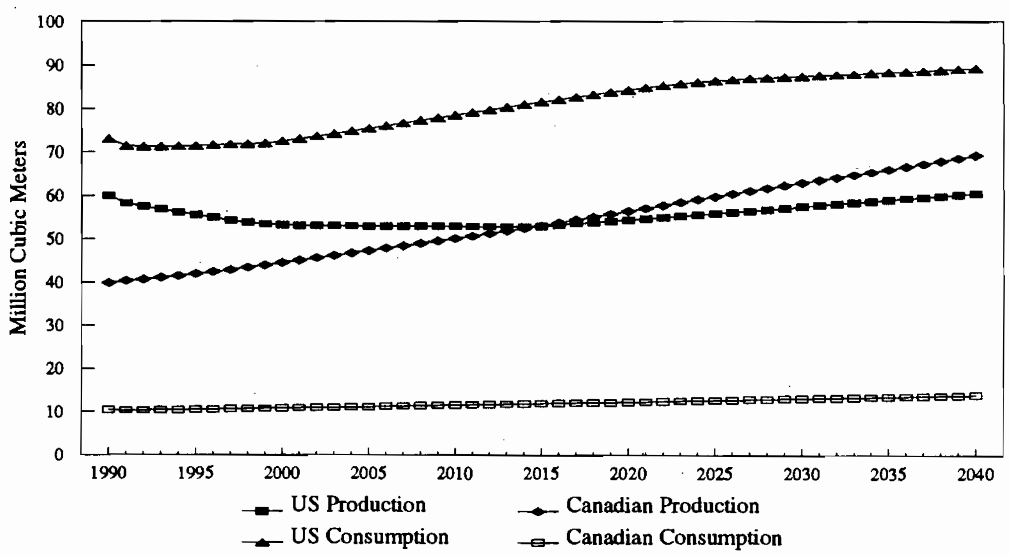

Figure 6: Softwood lumber production and consumption projection under base case conditions without canadian restrictions of timber harvest

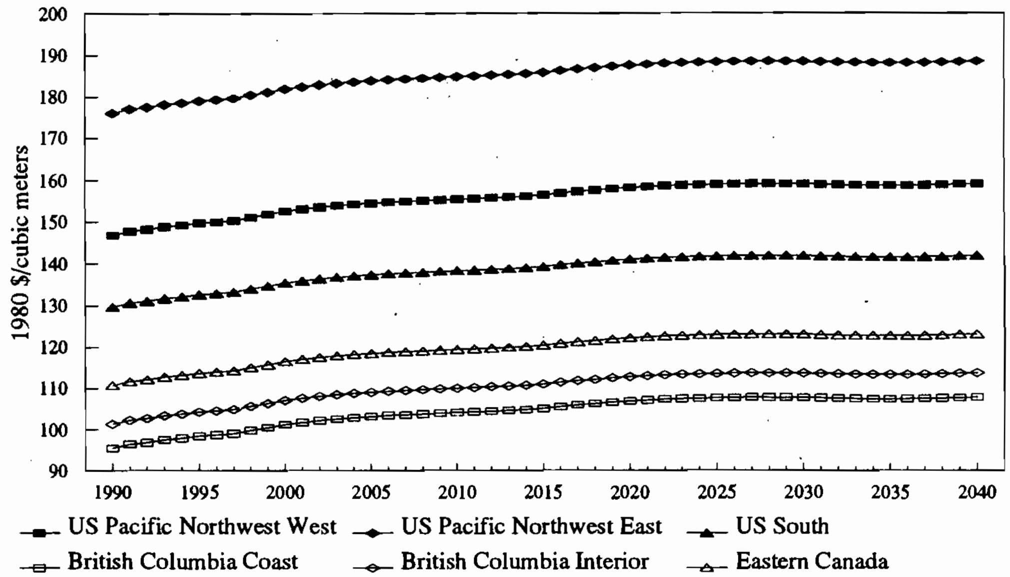

Figure 7: Projected softwood lumber prices
wtihout canadian restrictions of timber harvests.

Over the short-term, higher-cost producers harvest more area to offset the timber supply reduction. Anywhere from 1.12 to 1.61 hectares are harvested for every one hectare preserved, depending on estimates of timber stocking levels on the replacement hectares. The harvested area ratio increases to a range of 1.59 to 1.91 if Siberia were to expand its timber harvest levels.

Over the longer term, these impacts are aggravated as higher productive forest lands in the Pacific Northwest and British Columbia are replaced by less fertile forest lands. The annual loss in forest land productivity is estimated between 17 and 44%, depending on stock level assumptions and the response from Siberia. These annual productivity loses are cumulative and will add to the ratio of increased harvest areas to preserved area as high volume old-growth stocks are replaced by lower-volume second growth timber with longer rotations.

Consumers are the major losers. They pay $2.5 billion dollars as a result of the timber supply reduction. Mill operators also lose. Gains by southern mills are only 20% of the losses to mill operators in the west. Timber producers gain $1.4 billion dollars. These impacts are reduced substantially if Siberia were to expand its timber harvest levels.

Concerns over wetlands, other species preservation, federal below-cost timber sales, and sustainable harvests levels in other regions will add further strains on global wood supplies and cause a greater shift in regional timber production as others respond to offset any timber supply reduction. Additional supply constraints will exacerbate the impacts with more wood demand shifting to non-wood substitutes.

Environmental tradeoffs may be counterproductive because of this increased harvest acreage. While timber land is preserved in the US Pacific Northwest and British Columbia regions, greater areas are harvested to offset only 60% of the timber production decline. The shift from high to low productive areas may well result in new environmental problems. Non-wood substitution will increase carbon dioxide emissions, for example.

While current short-term market conditions show US prices well above those implied in this analysis, economic theory and the CGTM suggest these prices will come down as international markets adjust and international consumers absorb a portion of the cost. However, there are many concerns about the sustainability of harvests in other regions which may result in institutional constraints. Globalization of timber shortages may cause more difficulty than is evident from historical experience.

Tree Planting Program Impacts

Tree planting programs under two levels of funding and two different enrollment rates have a small impact on sawtimber harvests in the US with a smaller impact in Canada. Under the Moulton-Richards (M-R) funding level of $110 million, harvests levels in the US increase from 211.1 MMm3 to 217.3 MMm3 by 2040. A slightly higher level of 222.8 is harvested when the funding level of the program is doubled. The impacts on total Canadian harvests are a 2.3

MMm3 and 4.2 MMm3 increase over the base case harvest projection of 165.7 million cubic meters. These tree planting program impacts are illustrated in Figure 8.

Harvest levels under the Parks-Hardie (P-H) scenario at $110 million funding are higher. For the US, total harvests reach 227.9 MMm3. Canada reduces its harvests to 159.9 MMm3 under this program. With a doubling of the funding level, the program will increase softwood sawtimber harvests in the US to 237.1 MMm3. Harvests in Canada are furthered reduced by 3.2 MMm3 under the Parks-Hardie program. Figure 9 illustrates these impacts on softwood sawtimber harvests for the US and Canada. Table 1 provides the harvest levels achieved by 2040 under the different scenarios.

Table 1 also provides softwood sawtimber harvest levels under a restricted Canadian harvest regime. The M-R $110 level of funding scenario and the P-H $220 level of funding scenario were evaluated with a restricted Canadian harvest. The results suggest that a large portion of the Canadian decline in sawtimber harvest is not captured by US producers. A Canadian decline of nearly 60 MMm3 results in an additional US harvests of 9 MMm3 under the M-R scenario. Likewise, in the P-H scenario, a decline of 53 MMm3 results in an additional US harvest of 9.5 MMm3.

Table 1: Softwood Sawtimber Harvest Levels (MMm3)

Scenario	US	Canada	US	Canada
Base	211.1	165.7	Restricted Canadian Harvest	
M-R $110	217.3	163.4	226.3	103.8
M-R $220	222.8	161.5		
P-H $110	227.9	159.9		
P-H $220	237.1	156.7	246.6	103.8

As harvest levels in the US increase due to growth of the timber supply, softwood lumber production expands. Greater softwood lumber production in the US reduces the amount of imported lumber from Canada. Levels of lumber production in Canada fall and so do imports to the US. Lower lumber production reduces timber demand in Canada. The impacts of timber supply expansion are illustrated in Figures 10 and 11 for the Moulton-Richards and Parks-Hardie scenarios respectively. Production levels are also recorded in Table 2.

Table 2 also records lumber production levels under a restricted Canadian harvest scenario. Canadian harvest decline by 25 and 22 MMm3 in the M-R and P-H funding level scenarios respectively. US production of lumber increases by 6 MMm3 in both scenarios. Only one quarter of the reduced Canadian harvest is picked up by US producers.

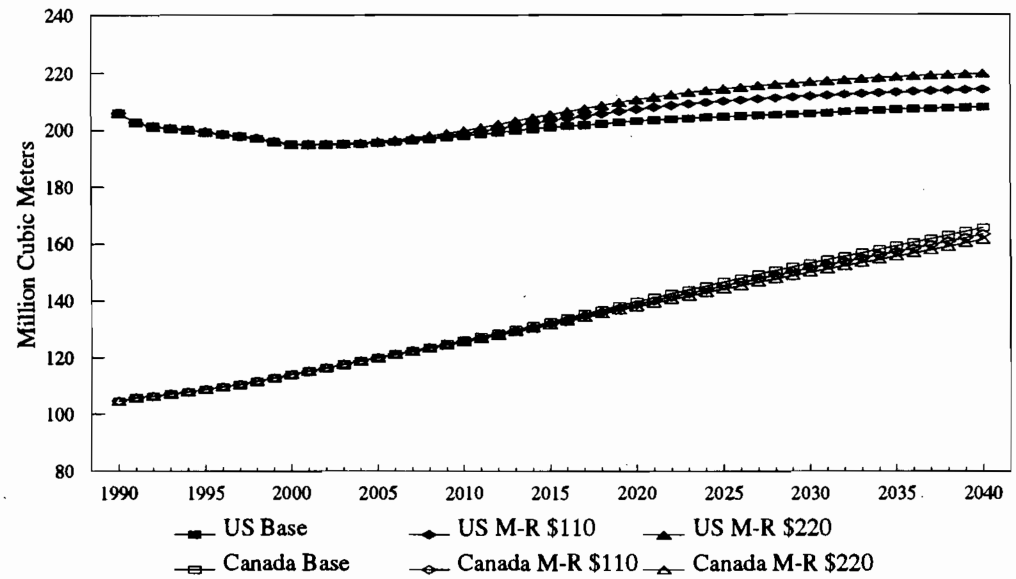

Figure 8: Tree planting program impacts on sawtimber harvests wtihout canadian restrictions of timber harvests.

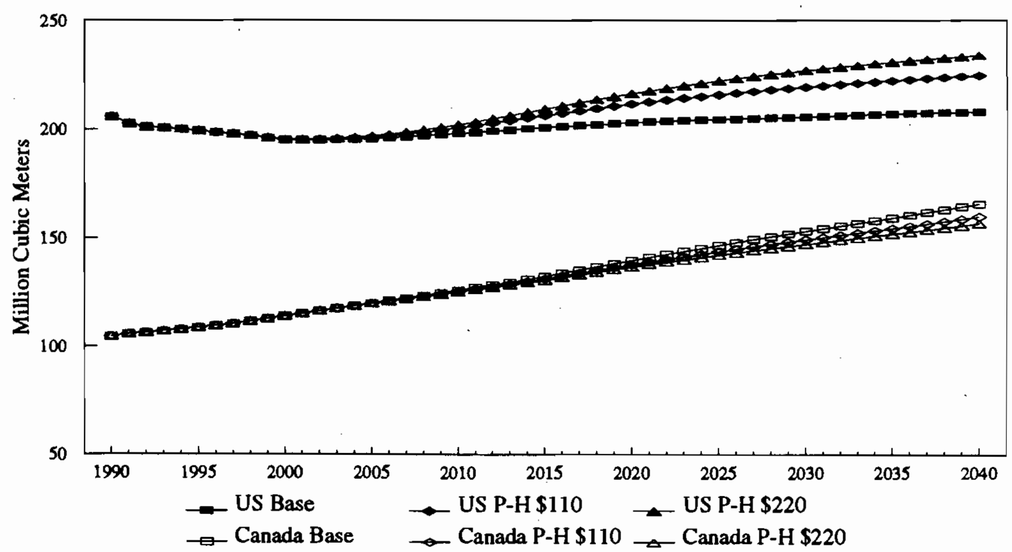

Figure 9: Tree planting program impacts on sawtimber production without canadian restrictions of timber harvests.

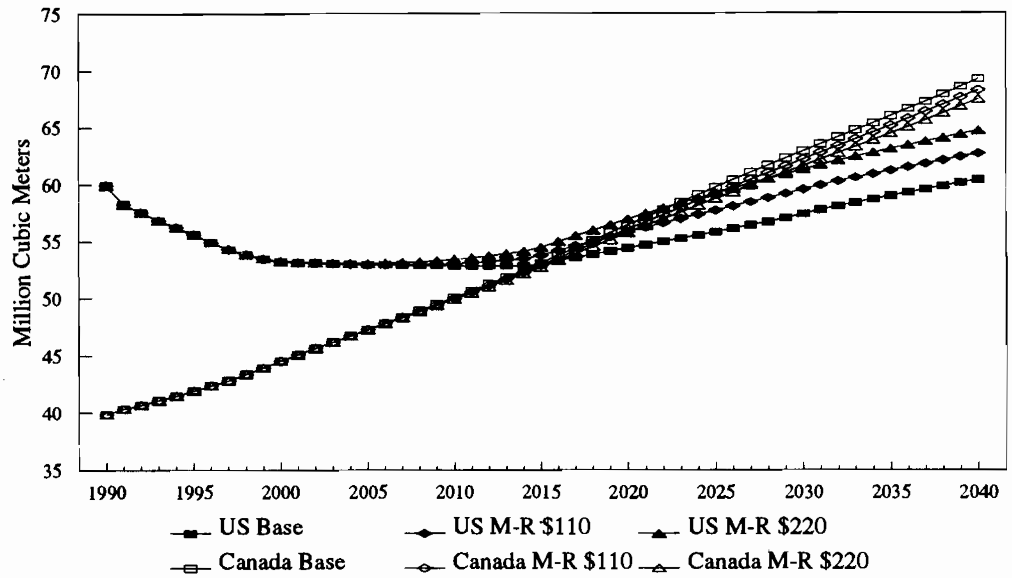

Figure 10: Softwood lumber production under alternative planting program lev wtihout canadian restrictions of timber harvests.

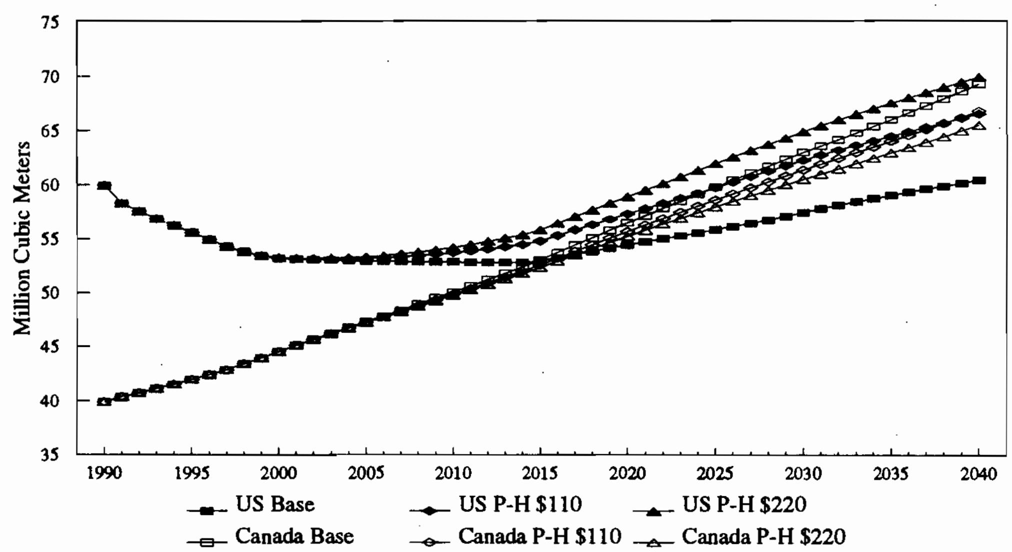

Figure 11: Softwood lumber production under alternative planting program lev without canadian restrictions of timber harvests.

Table 2: Lumber Production under Tree Planting Scenarios (MMm3)

Scenario	US	Canada	US	Canada
Base	60.6	69.3	Restricted Canadian Harvest	
M-R $110	62.8	68.3	68.9	43.1
M-R $220	64.9	67.5		
P-H $110	66.7	66.8		
P-H $220	69.9	65.4	75.9	43.1

Price impacts on softwood lumber markets are illustrate for the US South in Figure 12. Lumber prices under all the scenarios continue to increase with the exception of the P-H $220 level of funding. Under this scenario, prices for softwood lumber remain relatively flat, falling only three percent from the base price level of $141.90 per cubic meter.

Recycling Impacts

The impacts from increased recycling are more regionally disbursed and larger than the tree planting programs analyzed above. Imposing a 45% reduction in pulpwood requirement for producing pulp by 1995 results in increased harvests of nearly 50 MMm3 by 2040 in the US. Canada reduces its harvests by nearly 20 MMm3 as a result. The harvest increase results as pulpwood demand decreases and more timber is available for sawtimber harvests. This result must be viewed with caution, however, since the model assumes that the increase in sawtimber occurs at the margin between pulpwood and sawtimber. In fact, converting pulpwood to sawtimber may take more time than is implied in the model. It may be more appropriate to utilized the increase in volume associated with 2030 rather than 2040 since these numbers may be offset by ten or more years as pulpwood trees are permitted to reach sawtimber size. Even if this were the case, recycling appears to provide larger impacts on timber supply than either of the tree planting programs analyzed. The results of the recycling scenario are diagramed in Figure 13.

We observe larger price impacts in the log markets from increased recycling rates. These price impacts are evident in all the US regions, including the Pacific Northwest region Westside. We have provided a diagram illustrating these impacts for the US regions and Canada. These price projections are presented in Figures 14 and 15 respectively.

Discussion

The analysis suggests that land recruitment programs will not have a substantial impact on timber supply by 2040. The expansion of timber inventory would suggest a much larger timber supply entering the market. However, demand for timber captures only a portion of this new inventory. Stated alternatively, only a small portion of the new supply of timber would be managed for timber output. Larger areas of timber supply entering the market would depress

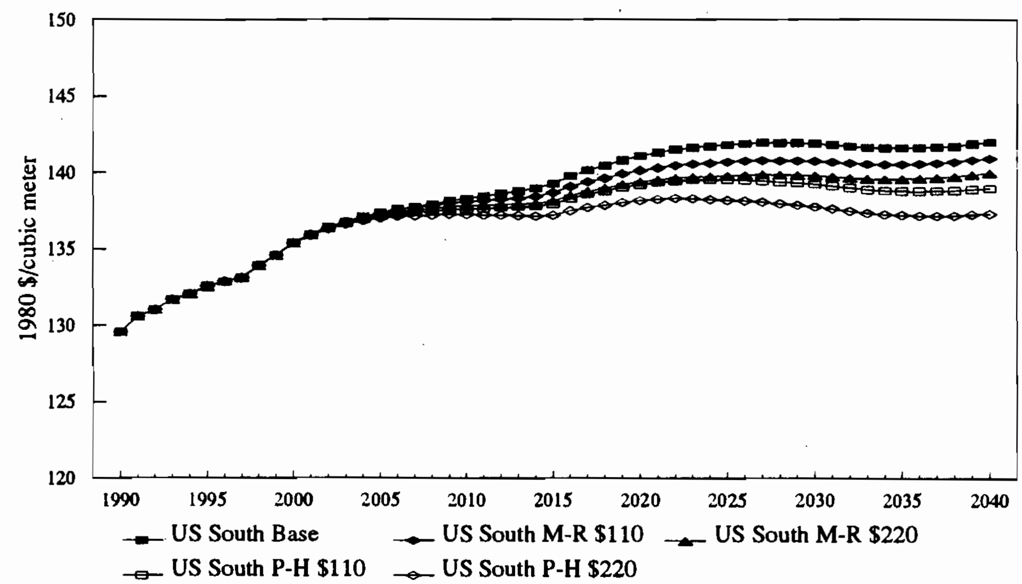

Figure 12: Softwood lumber prices under alternative funding levels wtihout canadian restrictions of timber harvests.

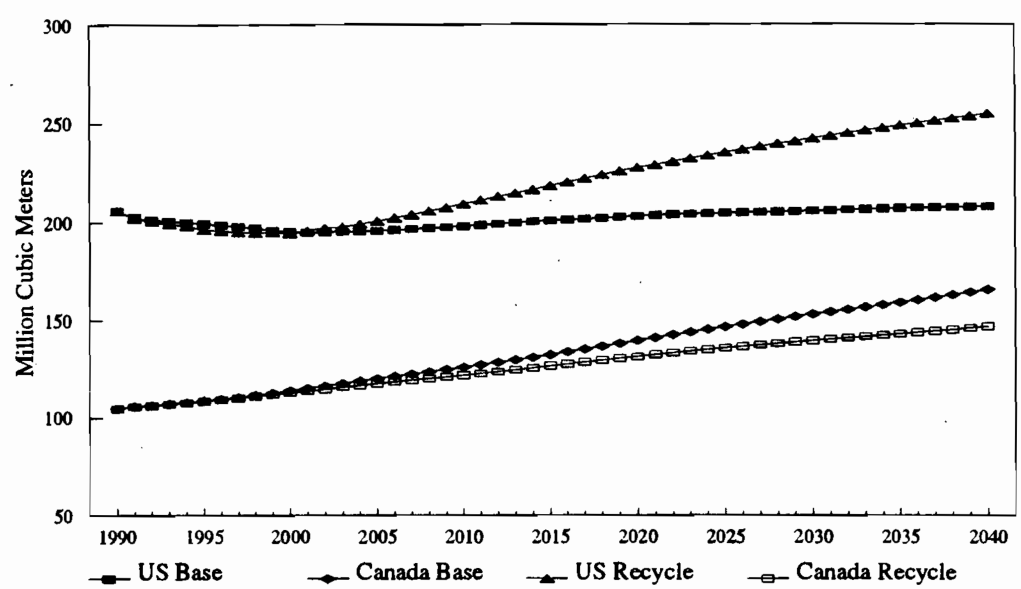

Figure 13: Softwood sawtimber harvest under recycling scenario without canadian restrictions of timber harvests.

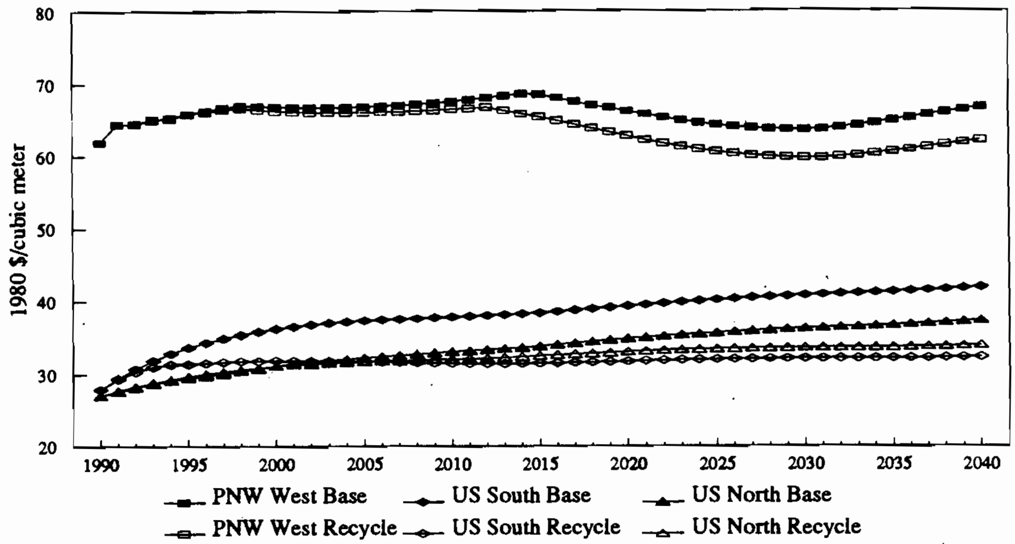

Figure 14: Softwood sawtimber prices under recycling scenario without canadian restrictions of timber harvests.

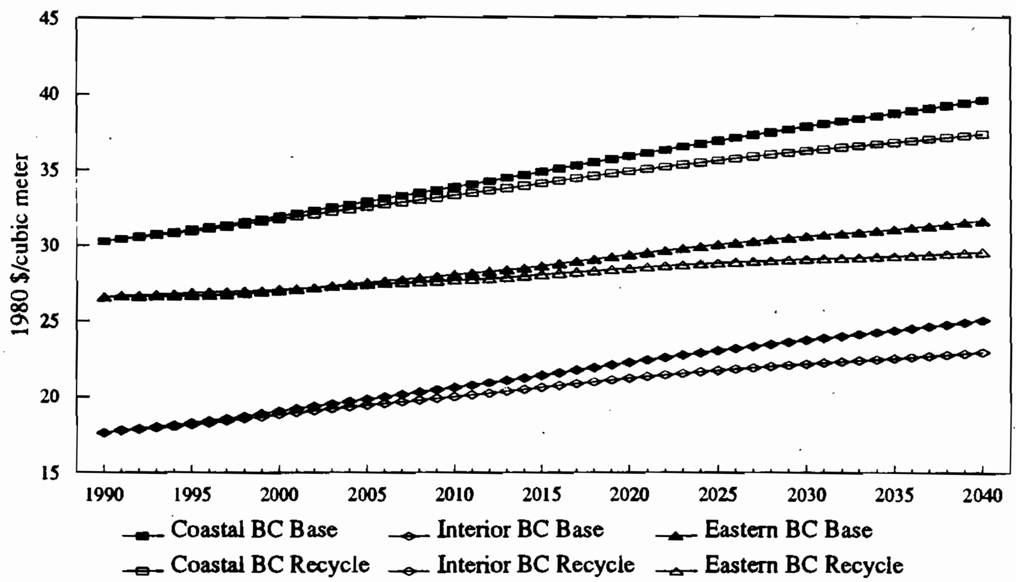

Figure 15: Softwood sawtimber prices under recycling scenario wtihout canadian restrictions of timber harvests.

timber prices. Rather than depressing prices, the model results suggest the amount of timber supplied would maintain economic profits for mill operators, timber owners and consumers.

This result also suggests that carbon storage may increase as land enrollment programs expand. The difficulty in accepting a larger carbon pool, however, lies in the management objectives of the participants of the program. If a large portion of the newly-enrolled areas do no enter into the timber market to capture the timber value, owners must then be compensated for holding onto their timber as a carbon reserve.

A second implication from the land enrollment program is since most acceptable lands are located in the South, the land recruitment program might reinforce the current restructuring of the US forest sector. This restructuring, as suggested by the base case analysis, indicates a shift in the production center from the western US region to the South.

The implication on carbon storage is not so clear, however. Considering the carbon storage potential of an acre of land, forest lands in the western US would clearly produce greater carbon storage benefits than those in the US South. However, the difference may not be large and it may be eliminated by placing a greater number of acres under carbon storage management in the South.

The results from recycling programs indicate a large price effect as more pulpwood logs are converted to sawtimber. The model's inability to recognize inherent quality differences between pulpwood and sawlogs may over-estimate the price effects. A better representation between the pulpwood and sawlog trade-off is required to substantiate the price gains suggested in this analysis.

While the analysis of tree planting and recycling programs has quantified the economic effects of these programs, it lacks any serious assessment of changes in the carbon accounts. Carbon accounting is the next step once economic impacts have been established.

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APPENDIX 1

CINTRAFOR Global Trade Model Background

The CGTM functions by computing a partial market equilibrium for the world's forest sector. The equilibrium approach considers how excess supply and excess demand interact to determine levels of production, consumption, price and trade flows. Components of the model include a demand sector for lumber and plywood, processing supply and timber supply, distinguishing between hardwood and softwoods. Market solutions for one period are updated by considering growth in final demand, processing costs, mill capacity, wood-using technology, and timber-growing stocks. Currently the model projects market solutions from 1990 to the year 2040.

The CGTM is useful to illustrate the impacts of policy decisions on supply and demand. The model allocates demand for processed products by selecting the least-costly producers. It currently offers strategic insight for business directions but not enough detail for product decisions. Its forecasts lack the data detail for the southern subregions and all products. Currently, the model does provide the capability to analyze changing market conditions globally under a set of alternative scenarios of resource supply, trade policies and demand conditions.

CGTM utilizes the mathematical programming approach suggested by Samuelson (1952) and incorporated by Kallio, *et al.*, (1987) in the IIASA forest sector model. The model equates supply and demand to determine the partial equilibrium prices and quantities by maximizing consumer and producer surplus net of transportation costs. The equilibrium solution is partial since only wood costs are considered explicitly in the model. Other costs, such as labor and energy are exogenous to the model. Constraints working on the model are (i) materials balance--in each region for each commodity consumption equals production minus net trade; and (ii) production capacity--production levels lie within the industrial capacity of each region.

Ten products are currently considered in the model: coniferous and nonconiferous sawlogs; coniferous and nonconiferous pulpwood; coniferous and nonconiferous sawnwood; coniferous and nonconiferous plywood; reconstituted panels; and wood pulp. These last two products are defined in the model as inputs to account for pulpwood and processing residual usage.

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. A large number of these regions have estimated demand functions for sawnwood and plywood. Final product demand is specified in constant-elasticity form using one of the following equations:

$$Q/I = a*P^b \qquad \text{or} \qquad Q = a*P^b*I^d \qquad (1)$$

where

Q is the product consumption (mm m^3 of product)

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

P is the product prices (real local currency per m^3 of product)
a, b, d are estimated parameters

The product supply specification is:

$$P = C + a*U^b \tag{2.1}$$

$$C = (ST + HD)*R_1 + MVMC - CHIPS*R_2 \tag{2.2}$$

$$U = Q/K_{-1} \tag{2.3}$$

where
P is the product price (real value per m^3 of product)
C is variable production cost (real value per m^3 of product)
U is capacity utilization
a, b are estimated parameters
ST is stumpage cost (real value per m^3 of log)
HD is log harvest and delivery cost (real value per m^3 of log)
R_1 is an input-output coefficient (m^3 of log used per m^3 of product)
MVMC is minimum variable manufacturing cost (real value per m^3 of product)
CHIPS is the price of wood chips (real value per m^3 of chips)
R_2 is an input-output coefficient (m^3 of product)
Q is product output (mm m^3 of product)
K_{-1} is production capacity at the end of the previous year (mm m^3 of product).

Like in most forest sector models the supply specification is fixed proportions: a unit of output requires fixed proportions of inputs. That is to say that timber is assumed to be consumed in fixed proportions to product output.

In CGTM, changes in production capacity is 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.

In CGTM 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:

$$P = a(Q/I)^b \tag{3.1}$$

where

P is the stumpage price (real value per m^3 of wood)
Q is the stumpage quantity (mm m^3 of wood)
I is the growing stock volume (mm m^3 of wood)
a, b, are estimated parameters

Timber supply in the public sector of the US West is modelled as:

$$P/P_s = a(Q/U)^b \tag{3.2}$$

where

P_s is a 3 year moving average of past stumpage sales prices
U is uncut volume in public forests.

As expressed in the stumpage supply equation, we assume that changes in inventory levels result in a one to one change in stumpage supply (*i.e.*, the inventory elasticity is equal to one).

The timber supply dynamics is an update of the inventory term using a growth-drain relationship:

$$I_{t+1} = I_t + G_t - H_t \tag{4}$$

where

G is timber growth (mm m^3 of wood)
H is timber harvest (mm m^3 of wood)

These dynamic elements of CGTM allow model solutions to be linked between time periods, but do not imply an optimal intertemporal market equilibrium solution. The dynamic structure in the model, although a simple procedure, captures many of the adjustments that would be expected in a more complete presentation of the forest sector.

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APPENDIX 2

Base Case Assumptions

Demand Growth

Demand growth for lumber and plywood products (equivalent to the percentage shift in the demand curve) for the US is depicted in Figures 1 through 3. After flat or negative growth in the early 1990's, demand is projected to pick up at less than 1% per year for the three major US regions.

Table 1 provides the annual percentage shifts associated with other demand regions in CGTM with estimated demand curves. In general the developed countries of the US, Canada, and Europe show an increase in lumber and plywood demand at around 1% per year. The Pacific Rim countries are projected to increase their demand by 3% per year or greater, with the exception of Japan, whose demand for wood products will decline. Lumber demand is expected to contract by 0.1% per year; hardwood plywood demand will shrink by nearly 1% per year. The projected decline in wood use demand in Japan is based on the assumption on that the growth of non-wood usage in the housing market will continue to expand. The Latin American countries of Brazil and Chile will expand the demand for lumber by 3% (Chile for softwood lumber) and 1.6% (Brazil for hardwood lumber). New Zealand is projected to increase demand by 1.1% annually.

Timber Harvest from Federal Timber Lands

Our base case has already reduced timber harvest from federal lands in the western US. These harvest reductions were calculated to account for the withdrawals of federal timber as a result of litigation to protect the northern spotted owl habitat. The reductions began in 1989 and timber sales are assumed to have reached a low point with several court injunctions that have delayed harvests. In the Pacific Northwest region Westside, timber sales declined from 19.7 in 1989 to 5 MMm3 by 1992. These levels were further reduced to 2.7 MMm3 by 2000. In the Interior region, public timber harvests were reduced from 19.9 in 1989 to 11.7 MMm3 by 1992. The harvests were further reduced in this region to 8.6 MMm3 by 2000. We analyze the impacts of further reductions in the US West and Canadian harvest levels in an alternative scenario.

Hardwood Production in Southeast Asia

Southeast log production is assumed to reach sustainable levels for Malaysia where severe shortages of commercial timber are becoming evident. East Malaysia reduces its harvest levels from 24.6 MMm3 in 1990 to 12.4 MMm3 in 2000. This level of harvest is maintained for the rest of the forecast period. West Malaysia reduces its harvest levels from 12.1 MMm3 to 4.7 MMm3 and maintains this levels of production out to 2040. Indonesia, with a large standing

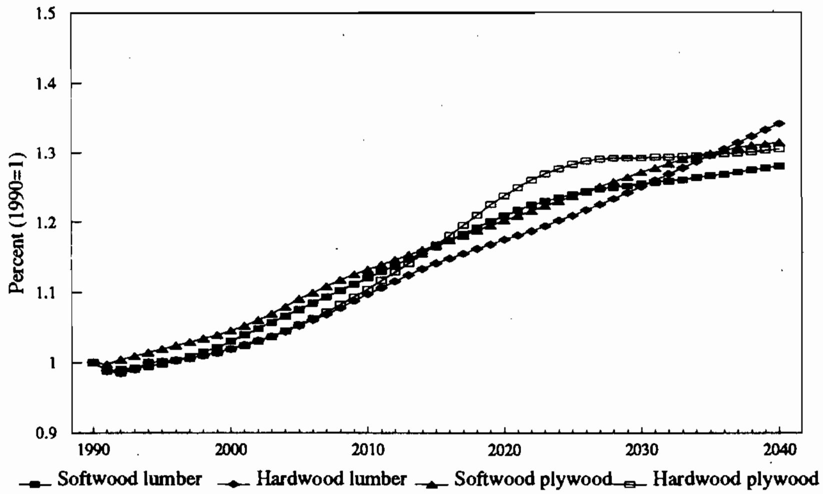

Figure 1: Demand growth in US South.

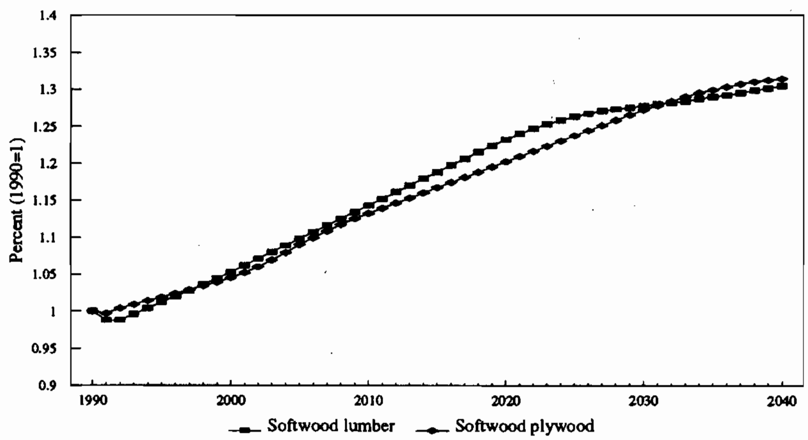

Figure 2: Demand growth in US West.

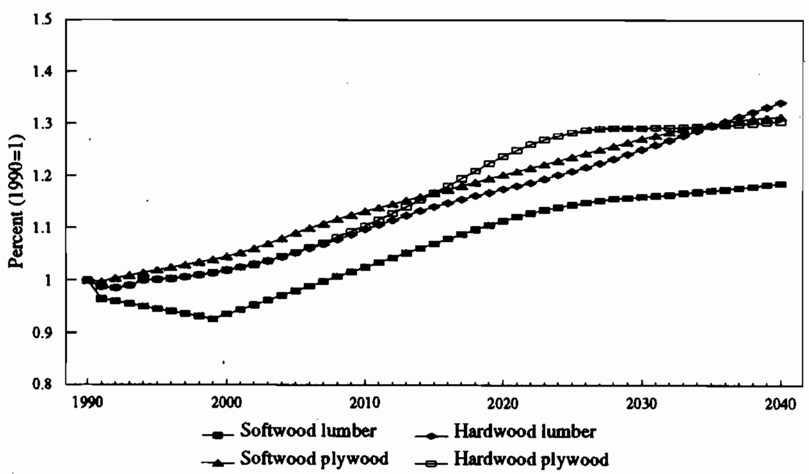

Figure 3: Demand growth in US North.

Table 1: Projected Demand Changes

Region	Product	Average Annual % Increase
Canada	Softwood and Hardwood Lumber	0.8
Finland, Sweden	Softwood Lumber	0.9
West Europe	Softwood and Hardwood Lumber	1.0
Japan	Softwood and Hardwood Lumber	-0.1
	Hardwood Plywood	-1.0
Korea	Softwood Lumber	1.0
	Hardwood Lumber and Plywood	3.4
Taiwan, Hong Kong	Hardwood Lumber and Plywood	3.4
Malaysia	Hardwood Lumber	4.2
Indonesia	Hardwood Lumber and Plywood	4.8
Brazil	Hardwood Lumber	1.6
Chile	Softwood Lumber	3.0
New Zealand	Softwood Lumber	1.1

inventory of commercial timber is not constrained to some fixed level of timber harvest in our base analysis.

The impacts of these constraints have recently been analyzed by Perez-Garcia and Lippke (1992). As a result of short supply and the lack of alternative suppliers, prices for hardwood logs are expected to increase. These price increases will impact the use of hardwood logs in end-use markets, particularly hardwood plywood.

Japan, Korea and China

The most significant assumptions on growth in Japan and Korea concerns their softwood plywood markets. In both case, these markets grow at a modest 0.5% per year. This assumption does not consider any substitution of hardwood plywood production by coniferous softwood production as may be the result of increasing hardwood log prices in these countries.

China is primarily an exogenous[1] region in our model since we provide projections of timber supply and product consumption. It is an important region, however, since, timber production will fall short of consumption expectations. China's import levels are assumed to increase from about 3.6 million cubic meters (MMm3) (projected) in 1990 to 13.3 MMm3 by 2000. Our projections for import levels for China decline after 2000 reaching 3 MMm3 by 2040. The decline in log imports is expected as domestic log production expands.

[1]An exogenous region in the model is a region where assumptions on production, consumption and trade levels are made to characterize the region. Economic behavior therefore is determined primarily outside of the model.

Recent exports to China have declined due to the shortage of foreign exchange. This situation appears temporary and projected demand for imports will continue to rise. There exists some evidence that China is currently importing a portion of its log requirements from the Russian Republics, North Korea and Mongolia under barter agreements.

Chile

Our model of Chile's forest sector is a simplified representation of a plantation economy. Allowable cut estimates are derived from data on plantation area, growth from these areas and minimum harvest ages. Total harvest from Chile is assumed to grow from 10 MMm3 to 22 MMm3 by the end of the century, afterwards increasing by 0.5 MMm3 annually. By 2040, the allowable cut in Chile will reach 30 MMm3. These estimates are based on the assumption that Chile will increase area under plantations throughout the forecast period and that the proportion of softwood to hardwood plantation areas will remain constant. Under short-rotation species such as radiata pine, these assumptions are not unreasonable since adjustments to plantation areas are possible within the length of the forecast period.

Harvest is divided into sawlog and pulpwood production. In our representation of Chile's plantation economy, we project pulp production (pulpwood demand) and derive sawlog production as a residual. As such, sawlog production is sensitive to pulpwood harvest levels.

Pulp production in Chile is estimated to increase to 3 million metric tons by 2040, from 0.8 million metric tons in 1990. Roundwood harvests are projected to increase similarly from 4.0 MMm3 in 1990 to 14 MMm3 by 2040. With the residual production of chips from sawmill activities, Chile produces an excess and increases exports of chips during the forecast period.

Given these projections of pulp production and roundwood harvests, Chile's sawlog production increases during the period 1990-2000 from 6.2 MMm3 to 16 MMm3, thereafter remaining constant as pulpwood harvest consumes the growth in allowable cut following 2000.

New Zealand

New Zealand is modeled in a similar fashion to Chile. The principal difference between Chile and New Zealand is that the former is projected to have a higher growth in pulp capacity, hence higher demand for pulpwood than New Zealand. Whereas in Chile pulpwood harvests continued to increase steadily throughout the forecast period, pulpwood harvest in New Zealand is projected to level off by 2020. As a result, lumber production continually increases throughout the forecast period.

The Russian Republics

In contrast to China, the Russian republics are expected to continue to supply export logs to the Pacific Rim markets, including China. However, the level of exports is projected to decline after 2000, when Chinese import demands are projected to diminish.