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THE IMPACT ON DOMESTIC AND GLOBAL MARKETS OF A PACIFIC NORTHWEST LOG EXPORT BAN OR TAX

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TABLE OF CONTENTS

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EXECUTIVE SUMMARY

A ban on the export of privately-grown logs has been proposed by some domestic log purchasers, environmental groups and congressional representatives to relieve the timber shortage caused by court injunctions and state and private land regulations in the Pacific Northwest (PNW). The assumptions behind this proposal are that: (1) log markets require some form of policy intervention--such as a log ban--to divert export logs to domestic mills; and (2) the benefits from added domestic log processing and export of finished products will outweigh the losses incurred by private timber growers, log exporters and consumers. Previous economic studies have generally shown that restricting open markets may benefit some processors, but these benefits come at the expense of others and with a substantial net cost to consumers. This study presents results which support the finding from previous studies that restricting open markets leads to higher costs with negative economic impacts in the restricted region, within the US and across the globe.

This study examines the assumptions behind a log export ban proposal. First, it draws attention to recent data on log export declines as evidence supporting the contention that open markets provide an efficient response to timber supply shortages. It then addresses the factors needed to determine the benefits and costs of a log export ban on global and regional markets: (1) how log and lumber trade flows are redirected and at what costs; (2) who is impacted regionally; and (3) who benefits and who pays at the log and lumber levels. The question of how an export tax differs from a log ban is also considered since log export taxes have been proposed as an alternative to a log export ban. This raises the general question of whether there are other forms of market interventions rather than a log ban that might relieve the log shortage for domestic mills with less negative impacts on other producers. Implications of the impacts of a log ban on job markets and forest management are discussed briefly.

The CINTRAFOR Global Trade Model (CGTM)--a product of over ten years of research by a number of international experts--characterizes regional timber, processor and consumer markets, and simulates the international flow of logs and products from wood surplus regions to wood deficit regions. The model is used in this study to analyze the global and between-region trade flow response to log export ban and tax policy proposals. This modeling exercise provides a first approximation of the proposals' impacts. Potentially important within-region issues--such as the location of timber relative to mill capabilities, and the many different categories of jobs that are impacted by changes in trade flows--are important areas of further research work.

Open market forces divert export logs for domestic processing: Data on log exports from Washington and Oregon indicate a 40% declined since 1989 as a consequence of higher regional timber and log prices that have been caused by the timber shortage. These data suggest that higher log prices under open market conditions have already redirected a substantial amount of previously-exported logs to domestic processors. If logs were banned from exports--*i.e.*, if closed-market conditions were to exist--the price conditions forcing the diversion of export logs to domestic markets would not exist. In economic jargon, open markets are more efficient than restricted or closed markets since open markets allow prices to stimulate the next lowest cost suppliers to replace the timber harvest reduced by policy constraints. Open markets faced with a timber supply shortage allow the price for timber--the product in shortage--to rise, coaxing out the next least costly increment in supply from around the globe. In contrast, a log ban supplements the wood available to processors in the log-deficient region by diverting logs from export markets. This form of market intervention prevents logs from reaching their highest valued markets. Log prices in the restricted region will then be lower even though timber harvest restrictions have reduced timber supply. Log prices will be higher in the alternative, unrestricted markets where timber supply was not reduced. Deviations from an open market response caused by interventions impose higher costs on consumers and a large number of processors. Only those processors within the restricted timber market will see lower log costs. Transportation costs to move the resources to global markets will also be greater under a ban or tax.

Lower prices reduce the supply in the timber short region: The CGTM estimates by 1995 a $48 per mbf decline in the PNW real domestic log price from a private log ban and a $150 per mbf increase in real log prices in Chile and New Zealand, two regions representative of remaining open market log suppliers. A similar $150 growth in real log prices is estimated by the model for Japan, the major log importing country. Real price increases are estimated to be much smaller in other markets that are not directly linked through trade to the Pacific Rim log flow. Price increases are measured as the difference between simulations of all regional markets after the imposition of a private log export ban from the PNW and baseline market conditions without a ban.

The lower real domestic price results in an annual 500 million bd ft reduction by 1995 in private timber harvest in the US West region. The redirection amounts to 21% of logs previously exported under baseline conditions. The countries previously importing US logs are only partially successful in offsetting their lower log trade volumes with the US by increasing their domestic log production and log imports from other regions. In this manner the previously importing countries offset only 15% of the log trade volume lost through the imposition of a ban. There do not appear to be enough open market log suppliers to offset the loss in Asia's softwood log imports from the US outside of Russia. While Russia may respond to this shortage, there is no economic history to characterize such a response, which in any case appears plausible only in the long term, given their current political problems.

Log importing country losses are much greater than PNW processor gains: The lumber volume reductions by overseas log-importing mills is far greater than the gains in log consumption by US mills. Lumber shutdowns in log-importing countries are 70% greater than additional processing in the US West. Higher log prices, the loss of higher-yielding lumber mills, and the decline in Western harvest levels all contribute to the greater decline in processing capacity in these regions. The large decline in overseas processing capacity implies significant reductions in their associated labor markets.

Canadians gain the comparative advantage in lumber markets: The volume loss in lumber production in log-importing countries is made up by greater amounts of lumber imports, almost totally from Canada. While the Canadian log export ban has shifted the comparative advantage to the US PNW in the Pacific Rim log markets, the log ban simulation indicates that a US log export ban will shift the comparative advantage in Pacific Rim lumber markets to Canada, and the comparative advantage in logs to New Zealand, Chile and perhaps even to Russia.

Consumers pay higher lumber prices even in the US: While the price of logs declines in the export-restricted supply market, other regions see log prices grow. The log price increase becomes an additional cost to lumber producers. US lumber prices rise 1.2% relative to the baseline. Other markets respond similarly with the exception of New Zealand and Chile. Lumber prices increase in these two markets as much as 30% due to a high growth in log prices.

Who gains and who loses: From an economic and social welfare standpoint the beneficiaries of habitat preservation--the policy action resulting in the log supply shortages--should pay for the cost of a program aimed at reducing the negative economic impacts on domestic mills from mandated timber harvest reductions. As a measure of a more equitable program, the US public should pay for the costs to offset the impacts of these constraints on timber supply since the beneficiary of federal habitat preservation policies is the US public.

Instead, under a log ban proposal, the model estimates an annual $395 million decline in timber value in 1995 for timber producers in the restricted region due to lower domestic log prices. This value declines further when the price premium for quality timber currently paid in foreign markets and not contained in timber received for domestic processing is included in the above loss. The log price premium is estimated to be $262 million, raising the total estimated loss to almost $658 million annually. The model estimates that the region's lumber producers will gain almost as much, as they see their log costs decline. According to the results, they also see a lift in national lumber market prices and their production volumes increase. However, it is the consumer that ultimately pays the bill. Since the model predicts that PNW log and lumber producers direct a high percentage of their production to the US national market, consumer costs in the western region are much less than lumber producers gain. However, the region still suffers a net loss when timber producer losses which include the export price premium are considered. US lumber consumer cost grows by an annual $218 million. Therefore, in the US, the consumer and PNW timber producer pay for implementing a federal policy to ban private log exports. An important implication from these results is that one can expect less investment in timber management which, over several decades, would result in sustainable harvests of lower volume and quality, forcing consumer costs to grow further as a result of the current timber producer's losses.

Since the model suggests that overseas log processing mill closures are greater than US production gains, it is not surprising that the international consumer pays even more than the US consumer according to the study results. Around 70% of the total annual $733 million increment in lumber consumer cost is outside of the US. The total global lumber consumer cost per volume of logs banned is almost $280 per mbf. The loss of higher-yielding processors and the use of more costly substitute timber causes the growth in global consumer cost to be large. The modeling results indicate that, while the principles of free trade offer global savings, a log export ban is a restriction to trade which adds to global costs, reduces global efficiency, and lowers the world's welfare. It also produces negative economic impacts in the log ban region greater than gains to lumber producers.

Preliminary economic and job loss estimates: The model characterizes the price and cost changes in lumber and log product flows at the regional level. Neither the within-region transportation costs nor job sensitivities to revenue impacts is directly modeled. Instead, the study uses changes in revenues provided by the model to arrive at preliminary measures of job market impacts. Revenues determine both the number of jobs and wage levels that can be supported, hence revenue impacts are the better measure of economic policy effects. Using a national average job cost in relation to the total value of gross domestic product, the US consumers' lumber cost increase of $218 million from a log export ban might result in a loss of about 5000 jobs annually across the nation. The PNW regional loss of more than $50 million would imply annual regional job losses of 1200 more than those gained by processors. In the longer term, regional losses would be larger as the harvest level declines with less investment in timber. In the short term, a poor distribution of mill capacities relative to the location of the timber currently being exported would also raise these job loss estimates. Since the revenue estimates only included the impact on lumber consumers, a full accounting for all forest products including panels and fiber products as well as the loss in port activities, could increase these job loss estimates significantly.

A log export tax as an alternative to a log ban raises revenues but with additional risks: A log export tax has the potential to collect monopoly rents for timber in shortage rather than to give the region's comparative advantage to other timber suppliers without any compensation. Global trade model simulations with an incremental tax on log exports indicated that the tax revenue declines rapidly with any log export tax greater than 13%. A 13% tax is equivalent to a $66 per mbf tariff on log exports, roughly 62% of the premium estimated for log export prices over logs for domestic processing in 1991. Results from the tax simulation indicate a 35% reduction in PNW log export volume, corresponding to a 19% decline in Japanese log imports.

Under a tax scenario, revenue losses by western timber producers are predicted slightly less than the proportionate impact of a log ban, processor losses increase, especially in log-importing countries, and the consumer costs are nearly proportionate to the costs under the log ban scenario. The modeling results indicate that the export tax, similar to the export ban, reduces timber prices. Hence, timber managers effectively pay for the tax. In theory, the collected tax may be used to offset the negative impact of the tax on timber management. However, the results suggest that the tax revenue would not fully compensate for the timber producers' losses, even if it was allocated to them. Similar to a log ban, an important implication of the tax scenario results is that there will be a reduction in timber investments and harvests in the longer term.

Since a tax is collected from foreign buyers it poses both new legal and retaliation risks. Several conditions should exist in order to minimize the losses in the PNW region. It would be necessary (1) to channel the tax revenues to timberland owners to reduce their loss and maintain their investment, (2) for log export purchasers not to retaliate, and (3) for potential new suppliers like the Russian Far East not to receive an infusion of investment needed to increased exports. These are difficult conditions to control by the tax imposing regions hence an export tax policy incurs additional risks beyond those associated with a log export ban.

Other alternatives should also be considered: Open markets provide the most efficient avenue for response by timber producers and processors to alleviate timber supply shortages. Hence open markets are the best economic solution to timber shortage problems. Either a log ban or tax causes large welfare losses in the restricted region, the nation, and the globe. Therefore either would be less efficient than allowing the open market to guide the diversion of export logs to domestic mills. Since both a ban and tax penalize timber--the commodity for which supply has been reduced--any preferred alternative should insure that the benefits which are directed to those mills being impacted by log shortages do not exacerbate the timber supply problem. Furthermore, a tax, as is the case in a ban, does not reduce the cost to foreign buyers of timber and lumber who do not benefit from US preservation programs. The preferred economic alternative would be for the US general public--as the beneficiary of the habitat preservation--to bear the costs imposed by a policy to direct more logs to PNW mills.

A credit given to affected mills may provide these aspects of a more effective intervention program. Tax credits for processing wood will improve the domestic processor's ability to compete with foreign processors for logs, without negatively impacting the timber producer. A tax credit program would benefit domestic processors who could then bid part of the credit back to timber when making bids to purchase timber. This approach would reduce the negative impacts on timber producers and increase the management and the output of timber, two large negative outcomes of either a log ban or tax policy. US taxpayers who benefit from timber preservation might then pay for a larger share of the global cost through higher lumber prices, and the cost would be directly invested in making US processors more competitive. Such a program can be considered economically efficient relative to the intended goals--such as reducing job market and investment behavior impacts--even though its costs would be absorbed by the US consumer with associated job losses nationally rather than regionally.

Introduction

A ban on the export of timber produced on private lands has been proposed by some domestic log purchasers, environmental groups, and congressional representatives to relieve the timber shortage caused by court injunctions and private and state land regulations that are responding to habitat reductions and the Endangered Species Act. The assumptions behind this proposal are (1) log markets require some form of policy intervention--such as a log ban--to divert export logs to domestic mills, and (2) the benefits from added domestic log processing and export of finished products will outweigh the losses incurred by private timber growers, log exporters and wood product consumers. Previous economic studies have generally shown that restricting open markets may benefit some processors, but these benefits come at the expense of others and with a substantial net cost to consumers. A thorough evaluation of the impacts associated with a log ban is needed to assess whether the proposal has merit or is counterproductive in creating a substitute timber supply and with it, more jobs for the region.

Economic arguments against trade interventions exist throughout the economic literature. Perhaps the most compelling argument against a log ban is the adverse effect it has on timber supply. A log ban attempts to reduce a shortage of domestic timber. However, the ban diverts logs from international markets to domestic mills without increasing the supply of timber. That is, while the ban partially reallocates the flow of previously exported timber to domestic mills, it does not create a substitute supply of timber.

Furthermore, the log ban may not result in the direct substitution in the regional economy of processed products for log exports. There are many factors affecting the possible substitution of unprocessed logs for processed products. For one, there are several other suppliers of logs in the international markets: logs from these suppliers will substitute for logs from the Pacific Northwest region. Second, a diversion of logs from the export to the domestic market will change the competitiveness of mills and lead to changes in production and trade patterns in the lumber markets globally. Lumber producers with larger shares of export markets than the US Pacific Northwest will benefit more so from an increase in international lumber demand. If foreign lumber producers are more competitive, they will take a larger market share. The changes in the patterns of production and trade in forest products affect a region's ability to directly substitute lumber products for unprocessed logs from the restricted region in export markets, an often-stated goal of log export ban proposals.

Globally, a larger set of impacts occur. Trade restrictions will generally increase the cost to consumers internationally as a consequence of diverting the flow of products from the most efficient international producers to consumers. Even US consumers may pay more as a consequence of constraints on the international flow of logs. Some market participants will gain, such as those mills which can bid for timber with less competition. Other participants such as timber owners, ports, exporters and many consumers will lose.

Furthermore, imposing trade restrictions can significantly impact other trade negotiations since trade restrictions raise reciprocity issues between nations. Trade restrictions contain possible implications of the international fairness of the restrictions, and can potentially provide reason for retaliation.

Over the last decade several studies have attempted to provide some measure of the impact on gainers and losers of log export bans (Wiseman *et al.*, 1981), (Parks *et al.*, 1981), (Haynes *et al.*, 1981), (Margolick *et al.*, 1986), (Sidabutar, 1988), (Vincent, 1988), (Scott, 1989), (NEA, 1981, 1988, 1989), (Flora, 1989) and (B. Lippke, 1992). These studies have shown that while there will be large wealth transfers between different groups, the economic losses to the exporting region exceed the benefits to others. It is not difficult to understand why. If the price foreign buyers are willing to pay for a quality range of US logs is much higher than that which domestic processors are willing to pay, then there are negative impacts from a log export ban. If foreign buyers do not pay a premium for at least some grade sort of logs then there would be no motivation to export any logs, except when surplus to the domestic markets.

Job impact is a critical parameter to be measured when assessing the effectiveness of trade restrictions. A log ban may support more mill-processing jobs but will cost log export-related and forest management jobs, possibly producing a net loss in overall jobs and reducing forest management levels. That is, if we account for the net effects of an increase in lumber costs, the decline in timber values and the loss of export premiums, net job losses may be greater than mill-related job gains.

Restricting the markets for timber will impact the price of timber and thus both the rate of investment by timber managers and sustainable harvest levels. These impacts combined with reduced log export handling and port activities may be larger than any benefits received by processors through higher mill-related employment.

Study Purpose

A complete assessment of the impacts of a log ban proposal requires an integrated analysis of the timber and product markets, related job markets, and investment behavior impacts. Many of the job market estimates as well as potential investment decisions require baseline information on production, trade and prices in the timber and product markets. The purpose of this study is to provide estimates of changing production and trade flows and prices so that (1) an economic assessment of who gains and who loses in the forest products sector can be produced, and (2) further studies of job related and investment decision impacts can be implemented.

The study is not without its limitations. It utilizes a model which is specifically designed to capture changes in competitiveness based on wood availability between different regions around the world. While competitiveness is a very important consideration of trade restrictions, the model ignores within-regional issues such as the location of short-supplied mills relative to the timber currently being exported and the suitability of these mills to process the timber impacted by export constraints. A further analysis of the timber and lumber markets should consider these important local-level issues. Also, as previously mentioned, the study is a starting point for a more detailed analysis of the jobs-related impacts due to log export restrictions. We provide an approximation of job impacts using a simplified approach. A more thorough analysis of job impacts applying employment input/output models is beyond the scope of this project. Thirdly, the study characterizes a global situation. This is important in two respects. Regional specification (as already mentioned) as well as product aggregation limit the results of the modeling approach to rather broad characterizations of international market interactions. Hence market adjustments reflect global, longer-term adjustments in production, consumption and trade patterns and prices rather than short-term fluctuations.

Nevertheless, the modeling approach presented here provides a complete global analysis of open market efficiencies and trade intervention policies. The study provides insights on the impact of restrictions on wood processing competition at the broader, between-region level. This is an appropriate starting point for a more detailed evaluation at a subregional level, since the PNW region is the major supplier of logs to Pacific Rim markets. Finally, the study supersedes an earlier analysis of trade constraints using this same model (Perez-Garcia, 1991) by reflecting the recent impacts of supply reductions being experienced in the PNW, reductions in tropical hardwood supplies and expectations for reductions in supply from British Columbia in its reference baseline condition.

Methods and Analyses Performed

The study utilizes the CINTRAFOR Global Trade Model (CGTM) to measure open market efficiencies and the impacts of trade restrictions. CGTM characterizes timber, lumber and panel markets around the globe. It is able to characterize global competitive shifts caused by supply and demand changes due to export constraints and taxes. A description of the model is provided in the Appendix.

A baseline reference case reflecting open market efficiencies using results from a recent study of timber supply constraints with the CGTM (Perez-Garcia, 1993) is used in the analysis. To implement the trade restriction analyses, this BASE CASE is used as the reference point to measure market conditions with no trade restrictions on log exports from the private sector. An alternative case--BAN CASE--is then constructed by restricting the flow of logs from the Pacific Northwest region[1] to zero. The difference between these two cases represents the impact of the BAN on the competition between forest products at the broad regional level. A second scenario--the TAX CASE--is constructed to weigh the impacts of a log export tax. The TAX CASE is evaluated against the results obtained in the LOG BAN CASE and the BASE CASE.

The first year of simulation in the model is 1990. To simplify characterization of results which change over time, the impacts in 1995 were judged to be a representative impact. By 1995, most of the full impact of the log ban or tax will be reflected, *i.e.*, there has been enough time to permit adjustments in timber inventory and production capacity to be fully realized in all

[1]The Pacific Northwest region includes the western portions of Washington and Oregon, west of the Cascades crest.

regions. The modeling results are reported for 1995 and represent annual, not cumulative, impacts. Both the ban and tax are imposed in 1991 in the modeling simulations. Prices reported in the study are expressed in 1992 US dollars.

By simulating the impact of regional supply and demand changes on trade flows under *pre-ban* baseline conditions and comparing them to the changes resulting from a restriction on the export of logs from the Pacific Northwest, the study characterizes the impact of a ban on international markets at the regional level. Changes in harvest and processing levels, timber and product prices, and trade flows by region and owner group are determined, thereby measuring the changes in costs to sellers, intermediate buyers, and consumers. The study measures the significance of the trade diversion that occurs in both logs and lumber, and the costs associated with a ban policy.

In addition the study analyzes the impact of an export tax in lieu of a ban. Export taxes on unprocessed logs have been proposed as a mechanism to reduce the impact of the timber shortage (Wilderness Society, 1991). An export tax has the potential of capturing a portion of any monopoly rent that might be associated with products that are in short supply. A ban, on the other hand, will force a region to give up its competitive advantage in logs to other regional suppliers without any compensation to the exporting region. The study therefore shows to what degree an export tax reduces the negative impacts that are observed for an export ban if revenues were to be invested in the affected region. Again, the impact of a tax is compared to baseline conditions before a ban or tax is implemented. In addition the differences between a ban and a tax are also reported.

The study uses the economic concept of consumer and producer surpluses to quantify welfare transfers for the US and the globe. Consumer surplus represents the total amount consumers are willing to pay for a specified quantity of product. Producer surplus represents the producer's profit: gross revenue minus production costs. The model uses a linear programming approach which maximizes these welfare measures to determine the equilibrium prices and quantities. Since welfare measures are computed as part of the equilibrium calculations, the study reports the economic welfare implications from forest sector policies along with other model results.

The study also employs the relationship between costs and gross domestic product to arrive at a preliminary employment impact associated with the log ban case. Revenue changes derived from the modeling results are used to provide preliminary employment impacts.

Price Signals from Open Markets Shift Export Logs to Domestic Mills

A focus of this study is to analyze the impacts of a ban on private log exports. As a beginning, it is necessary to examine the behavior of global timber markets in light of recent supply changes in both the US and Canada as characterized in Perez-Garcia (1993).

The most important result of the model simulations in Perez-Garcia (1993, the "PG study") relevant to trade policy impacts is that the growing shortfall of timber from the PNW and

Canadian west coast suggests a 16% redirection of trade flows around the globe. The timber supply reduction examined in the PG study caused regional log prices to increase relative to other regions. This price signal is used by log producers to redirect trade flows. As a consequence, log exports from the region decreased since log prices paid by mill owners were higher. The federal timber supply reduction lowered global log production. While log prices rise to coax out more production, new sources did not fully replace the supply reduction. This overall supply reduction caused a 23% reduction in logs exported. In combination with a greater response from private timber producers resulting from higher log prices, a substantial diversion to domestic processors was achieved without any form of market intervention.

According to Warren (1993) log exports have declined 40% from 1989 to 1992 (since the supply restrictions took effect), whereas the PG study estimated a 23% decline by 1995. The difference in log exports is explained by the global, long-term equilibrium nature of the model projection. Actual market forces in the short term may be more extreme than projections since the model simulates a long-term equilibrium after all global suppliers have had time to respond. In reality one could expect for local log prices rise more than in the model simulation until there has been time for the economic signals to be transmitted around the world with each region responding with changes in supply and demand.

A Ban Reduces Log Exports by 2.6 Billion Board Feet

In the present study, the model results suggest that the imposition of the log export ban would eliminate 12.5 million cubic meter (mmcm) (2.6 billion board feet (bbf)) in log exports by 1995. The 12.5 mmcm is the log export global equilibrium level suggested by the BASE CASE model simulation. It should be noted that the BASE CASE log export level is below the historic levels of the 1980's, but above current export level. That is to say that log exports under the model simulation do not decline as much as recent data has suggested.

The simulation suggests that the log ban will cause a reflow of wood at a higher cost and reduce the global efficiency of wood production. The log ban supplements the wood available to local processors by diverting export logs to domestic mills. The effect of the log ban is to lower regional log prices rather than to allow market prices to rise in response to the timber supply reductions. Log prices will be higher in the alternative, unrestricted markets where timber supply is not reduced. This higher log price actually expands global log production but reduces the harvest level in the previously exporting market. The net effect is for the global efficiency of wood production to be reduced since more logs are used to produce less lumber globally.

The simulation further estimates that, in the PNW, domestic log prices decrease 8.5%, from $117 to $107 per cubic meter (cm) ($569 and $521 per thousand board feet).[2] The log exporting countries of Chile and New Zealand see their log prices rise 22.7 and 40.6% respectively, from $130 to $160 per cm in Chile and from $73 to $102 per cubic meter in New Zealand. The

[2]Note: All prices are expressed in 1992 US dollars; prices for US regions will be presented in metric terms followed by board foot equivalents

increase in international log prices is several times greater than that caused by the owl conservation supply reduction in the PNW, as the international demand for logs is being provided by a significantly reduced set of suppliers. Over the much longer term, these prices may motivate a substantial increase in investments in additional rapid growth plantations and a resulting decrease in prices when these plantations mature.

The primary log-consuming markets of Japan, Korea and Taiwan-Hong Kong witness log price increases of 9.4, 6.3 and 9.1% respectively; from $313 to $343 in Japan, $162 to $172 in Korea, and $325 to $354 in Taiwan-Hong Kong according to the BAN CASE simulation. There are relatively small changes in log prices in other US and European markets, since these markets are either constrained from direct participation or too distant to be competitive in the PNW log market.

The diversion of US log exports to domestic markets and subsequent decline in log prices reduces harvest levels in the PNW region. The simulation indicates that the total harvest from the PNW region declines from 38.9 to 36.3 mmcm (7.78 to 7.26 bbf), a 6.7% drop. This 500 million bd ft decline in harvest represents 21% of the log export levels. Log consumption by mills in the region increases from 30.0 to 40.6 mmcm (6 to 8.12 bbf) as a result of the log export ban.

This result assumes that logs that were exported from the region can reach an existing mill without additional cost. In reality there may not be mills within the geographic range of the export-restricted timber close enough to purchase these logs, requiring a substantial increase in hauling cost and therefore a lower effective price for the stumpage. This would further reduce the harvest until competitive new mills were constructed closer to the formally exportable timber. A more thorough subregional analysis would be required to assess these impacts in the short term.

In addition, over the longer term, the reduction in timber prices would be expected to reduced timber management and lower the sustainable harvest level. It should be noted that the simulation does not impose these constraints, nor does it estimate how much the harvest would eventually decline in the longer term.

The shortage in logs in the Asia-Pacific region invokes different responses from each of the trade-linked markets. The log-importing countries of Japan and Korea together reduce log consumption from 43.5 to 32.8 mmcm, a reduction equal to 86% of the BASE CASE log exports. Japan expands its domestic production from 17.9 to 19.5 mmcm, compensating for about 13% of the formerly exported log volumes from the PNW region. Some searching for new log sources occurs as the PNW region shuts off its supply of logs to the Pacific Rim countries. Chile and New Zealand, while constrained by the available harvests from mature plantations, increase their combined log exports by 0.3 mmcm--about 2% of the PNW log export decline. These countries are low-cost producers, not marginal producers, and are therefore producing at their capacity. These shifts in log trade are presented in Table 1.

Table 1 Log Trade Flow Shifts Observed from a Log Export Ban on the PNW Region (in mmcm).

Region	PRE-BAN	POST-BAN
PNW	12.5	0.0
Chile and New Zealand	11.4	11.7
Others	10.5	10.5
TOTAL	34.4	22.2

The redirection of log flows from the PNW changes the competitiveness of mill operators. Operators in the PNW region realize lower log costs, while those in the other Asia-Pacific regions (Chile, New Zealand, Japan, Korea, and Taiwan-Hong Kong) operate with higher log costs and face a potential reduction in processing. Log costs in other regions of the US and Europe are not faced with any significant change in their log cost structure.

The one region with a potential surplus of logs not considered in this analysis is the Russian Far East. Its supply has not been managed in response to market prices and therefore its response to a US log ban must be considered supplementary to the model simulations. Any increase in Russian log exports in response to the log shortage or an export ban could reduce the growth in international log prices and the rate of mill closures in Asia. While many infrastructure problems constrain the Russian supply in the short term, it could become a more significant competitor over time. The development of the Russian forest sector will require investments that may develop following a period of high prices. A consequence of any large investment in the Russian forest sector would be for global timber prices to decline after the Russian supply had expanded (Backman 1993).

While a log ban provides additional timber for PNW processors it also reduces the activity of exporters, revenue to timber growers, and jobs supported by their investments. A log ban also forces an even larger reduction in the overseas capacity which were previously dependent on logs. Since the supply of logs has already been tightened, there are not enough new log sources within a competitive transportation range to provide logs to these users.

Lumber Market Impacts Are Widespread

Lumber markets are characterized by a larger number of trade flows. As a consequence, with more markets available to respond to changes in lumber production in the PNW and the Asia-Pacific region, the magnitude of any change on each individual market is less than its corresponding log market. Lower harvest levels in the PNW region and lumber trade adjustments which offset the Asian lumber production decline induce a growth in lumber prices globally. Hence, at the global level lumber consumers pay more. Even in US markets, consumer prices increase 1.2%. Asian markets observe a 0.8% price increase. Canadian prices grow 1.7%. Chile and New Zealand see the largest price increase as their lumber prices rise nearly 30%.

Higher lumber prices stimulate higher production levels from the US and eastern Canada. The westside of the PNW region produces 36% more lumber, from 12.3 to 16.7 mmcm as a result of the infusion of previously exportable logs in the domestic market. The US South increases lumber production from 24.7 to 25.5 mmcm, a 3.2% growth as a result of higher timber harvest levels. The Interior region of the US also shows a modest rise in lumber production, from 10.2 to 10.6 mmcm, a 3.9% increase. Total US production increases from 57.9 to 63.6 mmcm, a 9.8% growth. Eastern Canada increases lumber production by 0.8%, from 37.9 to 38.2 mmcm.

These higher production levels in the US and Canada however are less than the total decline in lumber production from the Asia-Pacific countries. Asia sees its lumber production decline by 7.5 mmcm, from 30.8 to 23.3, 70% larger than production increase in the US PNW log exporting region. Chile and New Zealand's production declines by 13.2%, from 3.8 to 3.3 mmcm as they tend to fill international log (rather than lumber) markets. Table 2 illustrate the changes in lumber production according to the log ban simulation.

Table 2 Changes in Lumber Production
Due to Log Export Restriction (in mmcm)

Supply Region	**Production Increase**	**Production Decline**
US PNW	4.4	
Other US	1.3	
Canada	0.3	
Asia	7.5	
Chile and New Zealand	0.5	
TOTAL	6.0	8.0

The changes in lumber production patterns affect trade flows. While US lumber exports increase, the majority of these new exports--1.1 mmcm--goes to European markets from the US South. Total US lumber exports grow by 16.9%, from 6.5 to 7.6 mmcm. The PNW region ships new lumber production primarily to other US regions.

Canadian lumber captures nearly all of the Asian markets. Their exports to Asia grow four-fold, from 1.65 to 8.9 mmcm. Lumber exports from Canada to the US decline 23.9% from 19.9 to 15.1 mmcm.

While quality differences in lumber between Canadian and US producers is essentially ignored in the model, it should be noted that all of the logs subject to export restrictions are second-growth timber, whereas Canadian lumber is produced from largely old-growth timber. The Canadian log export ban, in the past, has assisted in developing an Asian preference for US logs to the degree that the Asian markets preferred logs over lumber. According to the simulation with CGTM, the US log ban eliminates the competitive advantage held by the US timber producer in these markets, giving Canadian lumber a greater competitive advantage in the higher-valued, Asian markets.

While these results reveal nearly no PNW lumber export substitution for PNW log exports in the Asian markets, they do suggest a larger PNW share in US lumber markets. Asia now becomes more profitable for Canadian lumber producers than the US, as lower log costs in Canada combined with higher lumber prices in Asia provide the Canadian lumber processors with higher returns when servicing the Asian markets. The PNW region, constrained from the higher-valued, international market, becomes more dependent on the US market and its housing construction cycles.

In summary, the log export ban simulation results implies the substitution of PNW logs in international markets by Canadian lumber and some logs from Chile. It is also possible that Russia's log exports will increase, replacing PNW logs in Asian markets. For the most part, log sourcing by the Asian log-importing countries is subsequently more costly given the already low federal timber harvests from the PNW region and the increased response from Chile and New Zealand as a result. Given the greater difficulty in finding additional low-cost materials, Asia loses 70% more production than the gains by PNW mills. The Asian consumers are forced to import a larger share of lumber at a higher cost, largely from Canada. US lumber exports to international markets do increase somewhat, mainly from the US South to European markets. Increased production from the US PNW region flows into the US domestic market, reducing lumber imports by 4.8 mmcm, a 17% reduction. Figure 1 summarizes the trade flow impacts from the log ban simulation.

The High Cost of Increased Processing

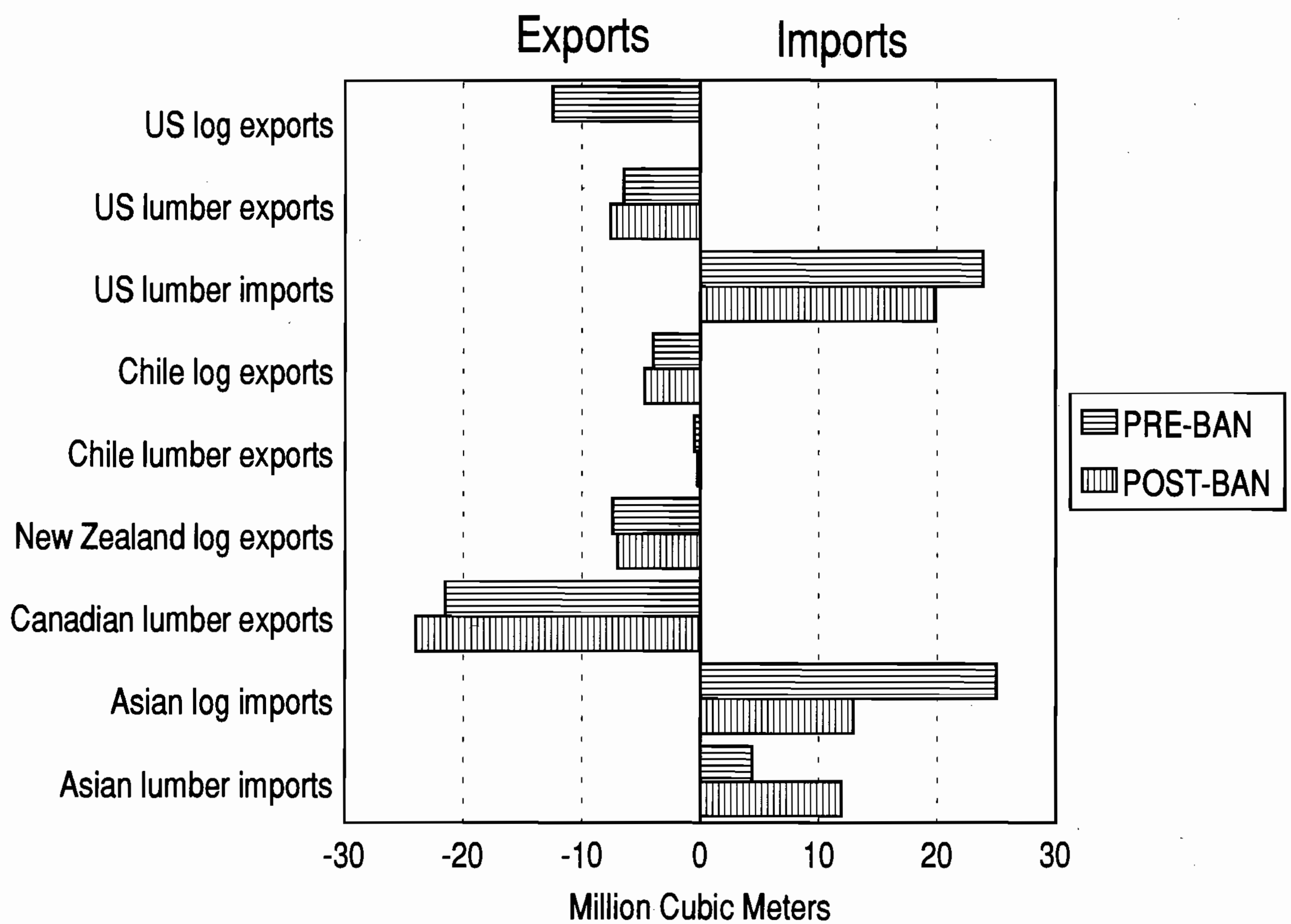
The log ban improves the position of PNW processors within the more cyclical US lumber markets, but decreases the competitiveness of Asian processors to supply their own lumber needs substantially more so. The Asian processor losses are greater than the US gains because of (1) the already substantial diversion of log exports caused by the harvest reduction in the US with higher, open market domestic prices, (2) the much greater log-to-lumber yield of labor-intensive, custom cutting Asian mills, and (3) the increased log costs to Asian processors. Alternative sources do not appear to be sufficiently available to substitute for PNW logs.

In the US, the log ban costs are largely born by PNW timber producers, even though it is PNW timber that has been reduced by harvest restrictions in domestic markets. The more efficient free market response characterized by the BASE CASE allows market price to encourage a greater volume response and implies a larger forest sector investment in the longer time frame. The ban allocates timber to local processors but regulates who must pay for the shortage. In particular, private timber producers in the constrained region are made less competitive than those in other regions.

In general then, there are three groups of losers: PNW timber producers, Asian processors, and global consumers. Losses incurred by these groups are greater than gains to PNW processors. Table 3 presents economic wealth transfers associated with the log ban for these three groups. There are additional losses by ports and export log handlers not characterized by the model and not reported in these three groups.

Figure 1 Trade Flow Impacts from a Log Export Ban in the PWN.

There is a shift in export market share as a result of the log export ban. Canadian lumber exports to Asia increase 7.2 mmcm, while exports to the US decline 4.8 mmcm. There is a net increase of 2.4 mmcm of lumber exports from Canada. US production increases 5.7 mmcm; of that, PNW substitutes 4.8 of the Canadian lumber. The US South increases lumber exports to Europe by 1.1 mmcm. There is a net export of 0.9 mmcm that can be exported from the PNW.



PNW timber producers lose nearly $395 million due to the decline in domestic log prices and the volume reduction. The loss to timber owners is understated since CGTM does not directly measure the premium in export log prices over that available from domestic processing. The export premium for logs of equal quality was recently estimated to be about $105 per mbf in 1991 (H. Lippke, 1993) or another $262 million, for a total loss to timber owners closer to $658 million. Timber producers which serve Asian markets gain over $1 billion, with the log-importing countries of Japan and Korea capturing nearly 50%. The gain by Chile and New Zealand timber producers is nearly as large as the losses to timber producers in the US PNW.

The global lumber consumer pays $733 million as lumber prices increase. Thirty percent of this higher lumber consumption cost is borne by US consumers, with Asian-Pacific consumers paying 38%. US consumers must pay

Table 3 Economic Transfers as a Result of a 100% Ban on Log Exports from the PNW Region (in million $US 1992).

Region	Timber Producer	Lumber Processor	Lumber Consumer
US West			
PNW Westside	-395.5*	403.9	
Other US West	85.8	-13.9	
Total US West	-309.8	390.0	-74.5
US South	52.7	26.6	-75.4
US North	13.4	0.2	-68.6
Total US	-243.7	416.7	-218.4
Canada			
Coastal BC	-27.5	42.4	
Interior BC	-81.7	137.4	
Eastern Canada	13.6	32.2	
Total Canada	-95.5	212.0	-32.0
Chile	244.0	-13.6	-82.4
New Zealand	299.0	-11.1	-85.4
Europe	161.2	31.2	-207.4
Japan and Korea	609.2	-1,032.0	-107.7
All Market Economies	974.2	-396.7	-733.5

*not including the loss in export price premium estimated at $262 million.

more for higher-cost timber even though the exports of raw material are constrained. As the previously-cited economic studies have shown, restrictions in trade will almost universally increase costs at the global level.

Gains to US lumber processors amount to $404 million, only 39% of the loss incurred by Japanese and Korean lumber mills and 55% of the global lumber consumer loss. The consumer would also incur loses in higher prices for other forest products such as paper and plywood.

Large Net Wealth Transfers in Freely Trading Log-Producing Countries

New Zealand and Chilean timber producers accrue large wealth gains through their practice of freely trading logs. Economic gains associated with opening a country's trade economy has been demonstrated in economic theory and by empirical studies. A primary result of the log ban simulation is that PNW timber owners lose wealth because of a closing of their log markets. But imposing the log ban on exports in the PNW encourages further trade in New Zealand and Chile, where gains to trade are expanded significantly, causing a large wealth increase. That is, the log export ban further closes the markets for logs, producing substantial gains for those countries that continue supplying logs.

To illustrate the net gains associated with a free trade practice consider Figure 2 which depicts the demand and supply curve for the log market in Chile (see Appendix for an explanation of a spatial equilibrium). The supply is constrained at 8.2 mmcm since there is a limit to the number of mature trees and hence the harvest in Chile. The demand schedule is the derived demand for logs from lumber demand. In the absence of any log trade, Chile would produce about 5.5 mmcm of logs at a price of about $25 per cubic meter. With log trade, Chilean producers harvest all they can--8.2 mmcm--at the higher BASE CASE international log price. Because log markets are open in Chile, there is a net wealth gain. That is, after theoretically compensating domestic processors for higher timber costs, timber producers can still retain a positive wealth gain.

The imposition of a log ban in the PNW raises the international log price. Chilean timber producers still can only produce 8.2 mmcm of logs, but they shift a portion of their production from domestic markets to international markets. It is still efficient to do so because the losses that domestic processors incur--depicted as area A in Figure 2--can be compensated by the gains to timber producers--depicted as the sum of areas A + B. There is a net gain of area B. Estimates for these areas for Chile are: loss to lumber processors of about $124.2 million and total gains to timber producers of $242.6 million. Net gains to trade amount to $118.4 million, an amount equivalent to area B in Figure 2.

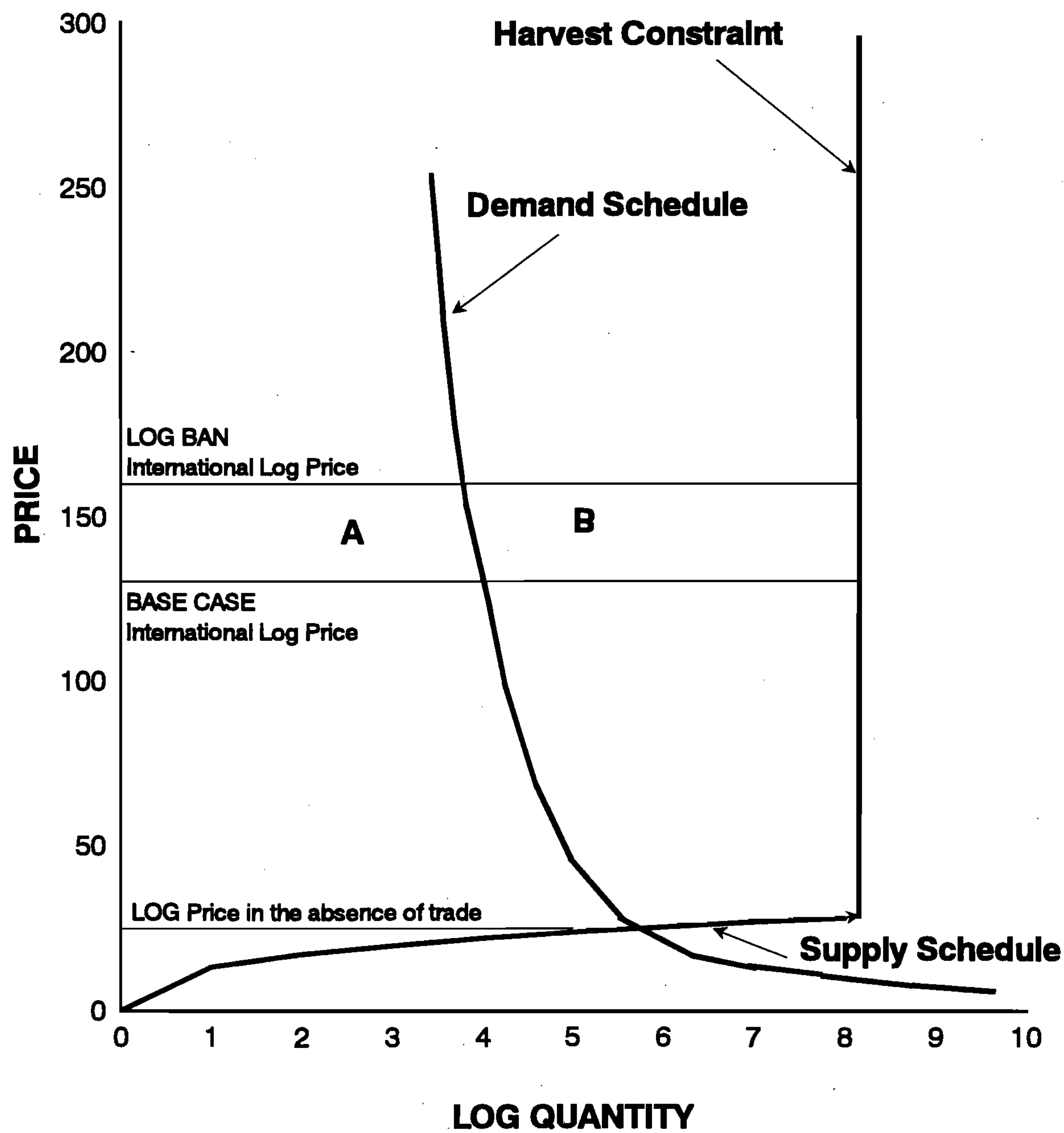
Generally speaking, export policies in the US are developed to open foreign markets further. A log export ban to reduce the impact of the timber shortfall to mill processors is a highly restrictive trade policy that would come at a high price to US consumers and PNW timber growers as well as foreign processors and consumers.

Economic and Job Losses

The model characterizes the price and cost changes in lumber and log product flows at the regional level. However, neither the within-region transportation costs nor job sensitivities to revenue impacts are directly modeled. Instead, the study uses estimated changes in revenues

Figure 2 Welfare Effects Due to a Further Opening of Log Markets in Chile be Imposing a Log Ban on PNW Producers.

Chilean timber producers, with harvesting constraint of 8.2 mmcm, gain welfare denoted by areas A + B with an international log price of $159.70 per cubic meters ($1992 US). Local processors lose area A. The net effect--free trade gains due to restricting log exports from the PNS--is a gain in welfare of area B. Estimates for area A and B are $124.2 and $118.4 million respectively. Total gains to timber producers are $242.6 million.



provided by the model to arrive at preliminary measures of job market impacts. Revenues determine both the number of jobs and wage levels that can be supported, hence revenue impacts are the better measure of economic policy effects. Using a national average job cost in relation to the total value of gross domestic product, the US consumers' lumber cost increase of $220 million from a log export ban might result in a loss of about 5000 jobs annually across the nation. The PNW regional loss of more than $50 million would imply annual regional job losses of 1200 more than those gained by processors. In the longer term, regional losses would be larger as the harvest level will decline with less investment in timber. In the short term, a poor distribution of mill capacities relative to the location of the timber currently being exported would also raise these job losses. Since the revenue estimates only included the impact on lumber consumers, a full accounting for all forest products including panels and fiber products as well as the loss in port activities, could increase these estimates significantly.

Timber Producers and Consumers Still Pay For a Log Tax but Revenues Could Compensate Timber Producers

The difference between a log export tax and a ban on log exports is the allocation of economic costs and benefits. Tax policy results in a collection of revenues which in theory are available to compensate those affected by the policy. In this case, the timber producer pays the tax and is the one who should be compensated.

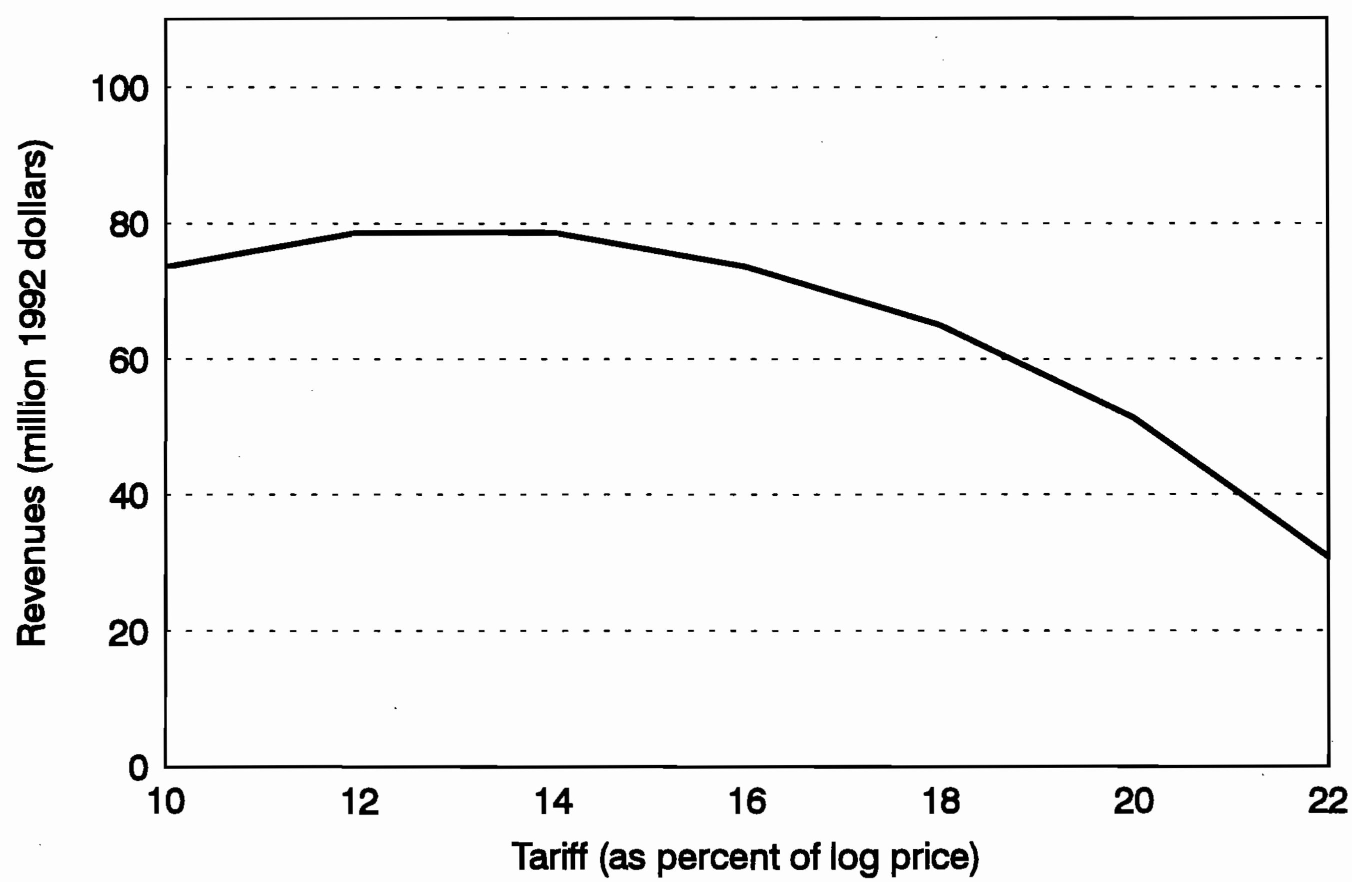
In order to determine the appropriate level of tax, CGTM was employed to search over a range of tariffs. The tax level was selected so as to yield the greatest returns in tax revenues. The logic behind this approach was to determine any inherent monopoly rents associated with log exports given the historical market conditions which existed in 1990. Figure 3 illustrates the different levels of revenues associated with different tariff rates. The high point--a 13% tax--was chosen to analyze the impacts of a tax on log exports.

Figure 3 indicates tax revenues would be highest with a tax of approximately $14 dollars per cubic meter ($66 per mbf). One reason for the low level of tax before revenues begin to decline is that domestic harvest declines have raised domestic prices even more than export prices. That is, the PNW cannot continue to push for higher prices overseas without reducing its ability to maintain profits in exports. At higher international prices, both log and lumber substitution from other sources erode the profitability of log exports.

An alternative interpretation of the monopoly rent is the price premium that PNW logs command in Asian markets. In the model, price premiums associated with higher quality and foreign processor advantages are accounted for by reducing the transfer costs associated with log exports. Calibration of log trade flows can be accomplished through adjustments in the transportation cost matrix. That is, historical trade flows for the calibration year--1990--are made equivalent to projected 1990 trade flows by adjusting the transportation cost matrix. A tax on log exports increases the transfer costs--the opposite of the price premium calibration. The $66 per mbf tariff represents approximately 63% of the estimated log price premium at the log level for 1991 and results in a decline of 4.4 mmcm in log exports.

Figure 3 Revenues Associated with Different Levels of Tariff on Log Exports from the PNW.

Maximum revenue is achieved between 12 and 14 percent and declines rapidly afterward.



The most significant result of the log tax policy analysis lies in the size of the tax revenues in relation to timber value, processing, and global consumer losses. In assessing the timber value, it is useful to associate them to export log price premiums. A tax versus a ban policy should attempt to compensate those groups adversely affected by the log tax by maintaining some of the overseas economic transfers occasioned by the log tax within the region. Table 4 presents the economic wealth transfers associated with the TAX CASE. Tax revenue collected amounts to $78 million and is $16 million greater than the losses incurred by the timber producers in the PNW, at domestic market prices. The revenues are slightly larger than the losses incurred by US lumber consumers and about 24% of the losses incurred by Asian processors. If the total tax revenue were to be allocated to compensate timber producers' losses, timber producers would still lose some portion of their log export premium (as much as $95 million, minus the $16 million if taxes were reallocated to timber owners and assuming the premium does not increase with higher price). An implication of this loss is that it would still reduce management investments in the region.

Tables 3 and 4 also provide information on how economic transfers are affected under a tax policy relative to a ban. Those most likely to pay for the tax are the same as those who were impacted most by the log ban since tax revenues are collected in the exporting region. Log-importing countries will still pay for the tax. Under the log ban Chile, New Zealand and the Asian domestic timber producers receive a sizable gain due to higher international log prices. These benefits are eroded with a tax. Timber producers in Japan, Chile and New Zealand under a tariff scenario receive the benefits similar to those of a ban policy, *i.e.*, higher returns to timber. There is a shift in the shares that lumber consumers around the globe pay. US consumers pay 28% of the global consumption costs with a tax--compared to 29.3% with a ban--whereas the Asian countries pay 41.3% with a tax--compared to 38.5%.

According to the tax simulation, the tax does not substantially change the proportionate burden on consumers or timber producers in the US, although it does increase the costs to non-US processors somewhat more than for US processors. The tax does not by itself redistribute costs to the US consumer--as the ultimate beneficiary of the environmental objectives behind the supply reductions--or to those US processors who benefit from the reduced log exports. Its only useful role would therefore appear to be to partially offset the decline in timber returns which would otherwise reduce long-term timber investment and harvest levels.

A log export tax raises additional legal complications, would likely be viewed more negatively as a trade barrier, and therefore would pose greater risks of retaliation. While the principle of a log tax instead of a ban has theoretical advantages, the fact that it does not greatly change the distribution of who pays, increases the risk of international retaliation, and will not offset the timber manger losses even if the total revenue is provided as compensation reduces its practicality.

Table 4 Economic Wealth Transfers as a Result of a 13% Tax on Log Exports from the PNW Region (in millions of $US 1992).

Region	Timber Producer	Lumber Processor	Lumber Consumer
US West			
PNW Westside	-62.1*	131.3	
Other US West	30.5	-15.0	
Total US West	-31.6	116.3	-24.8
US South	16.4	8.3	-25.1
US North	3.2	-0.1	-22.9
Total US	-12.0	124.7	-72.8
Canada			
Coastal BC	-11.4	16.2	
Interior BC	-32.5	51.0	
Eastern Canada	10.6	80.2	
Total Canada	-33.3	75.4	-10.8
Chile	85.6	-3.3	-33.5
New Zealand	108.2	0.6	-38.0
Europe	65.1	8.4	-69.1
Japan and Korea	197.2	-403.1	-35.9
All Market Economies	410.8	-197.3	-260.1

Tax Revenues amount to $78.0 million dollars

* not including the loss in export price premium estimated at $92.4 million

Other Alternatives May Exist

Open markets allow timber producers to response to processor demands through price signals to alleviate timber supply shortages. In this sense, open markets are the best solution to timber shortage problems. Either a log ban or tax causes large welfare losses in the restricted region, the nation, and the globe; and either would be less efficient than allowing the open market to guide the diversion of export logs to domestic mills. Since both a ban and tax penalize timber--the commodity for which supply has been reduced--any preferred alternative should insure that the benefits which are directed to those mills being impacted by log shortages do not exacerbate the timber supply problem. Furthermore, a tax, as is the case in a ban, does not reduce the cost to foreign buyers of timber and lumber who do not benefit from US preservation programs. The preferred economic alternative would be for the US general public--as the beneficiary of the habitat preservation--to bear the cost.

A tax credit for processing wood given to affected mills may provide the desired aspects of a more effective intervention program. Tax credits for processing wood should improve the domestic processor's ability to compete with foreign processors for logs, without negatively impacting the timber producer. A tax credit program should benefit domestic processors who could then bid part of the credit back to timber, reducing the negative impacts on timber producers and increasing the management and the output of timber. US taxpayers who benefit from timber preservation might then pay for a larger share of the global cost, and the cost would be directly invested in making US processors more competitive. Such a program can be considered economically efficient relative to the intended goals--such as reducing job market and investment behavior impacts--even though its costs would be absorbed by the US consumer with job losses nationally rather than regionally. Measuring the impacts of a tax credit program were beyond the scope of the present study but should become a constructive area for future research.

Summary

Neither a log export ban nor a tax results in net gains for the PNW, the region suffering timber supply reductions. Open markets already redistribute a large percentage of log exports to US processors, reducing the impact of the decline in federal harvests. The region's comparative advantage remains in its timber resource, not its processing technology. Both the log ban and tax reduce this comparative advantage, causing it to shift to overseas timber producers and Canadian lumber processors. While either a log export ban or tax can improve the competitiveness of PNW domestic processors, the gains to these mills are more than offset by losses to PNW timber producers, overseas processors, and all consumers. Even with the potential for collecting monopoly rents from a tax, there remains a net loss to PNW timber producers. The results of simulations of both the log export ban and tax impacts imply significant reductions in long-term forest sector investments and the sustainable harvest level.

The study assumes no response to trade intervention. Reaction from international countries may significantly change the results. The results are based on responses such as:

* Log export purchasers will not retaliate for either a log ban or tax on other products for which they hold an advantage;

* The Russian Far East does not respond with increased harvest through investments such as might be made by US or Japanese companies or other timber managers; and

* Tax proceeds are channeled back to timber returns to avoid a more severe reduction in timber management.

The magnitudes of the impacts of a tax or ban reported are conservative estimates since the analysis examined only lumber consumers and does not include the impact on port activities.

The study findings are consistent with many prior studies on log export bans and taxes. They lend empirical support to economic theory which states that open competitive markets are the most efficient allocator of resources. The results do run counter to the simplistic notion that exporting logs exports our jobs. Trade constraints have generally not been considered good policy unless national security is at risk. Timber is not likely to be critical to national security. Maintaining good relations with overseas customers is important to export performance and would appear to be more significant to the forest sector than its impact on national security. The net benefits to the region and nation favor open markets over either a log ban or tax.

The general results of this study also support the findings of an earlier study (Perez-Garcia 1991). The present study has considered new information on the reduction in timber supply and changes in the demand for forest products. A recent study by Perez-Garcia (1993) using this new information estimates that higher domestic prices will divert a substantial amount of log exports to domestic mills. Given the tight timber supply, there is less ability to force foreign prices higher with trade intervention policies.

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APPENDIX

Modeling Methods

The usefulness of the CGTM is that it maximizes net social surplus. Net social surplus is the sum of the consumer and producer surpluses. Consumer surplus is total expenditures minus the total willingness to pay by consumers. Producer surplus is total revenues minus total costs.

Surplus measures are obtained in both the product and factor markets. The derived demand for timber implies the same physical amount of timber per boardfoot of lumber, regardless of prices.

The CGTM is a spatial equilibrium model of the global forest sector. It is the result of 11 years of research; five years initially at the International Institute of Applied System Analysis (IIASA) in Vienna, Austria, and six additional years at the University of Washington. The present model is an updated version of the CGTM developed by Cardellichio and others at CINTRAFOR (see Cardellichio *et al.*, 1988, 1989). Data has been updated to 1990 with additional minor revisions to exogenous forecast. The following sections describes the general modelling approach used in CGTM.

The CINTRAFOR Global Trade Model (CGTM)

The CGTM projects production, consumption, prices and trade of ten forest products in 43 regions which comprise the globe. Given the demand and supply for each region, bilateral trade flows between regions, as well as transportation costs, the model solves for an equilibrium price, production, consumption and trade flow. It takes the equilibrium results for a base year and uses them to find equilibrium solutions for subsequent years by considering changes in demand, production and trade levels. These changes are implemented through submodels for timber growth, production capacity, and consumption. A detailed description of the model is presented in Kallio *et al.* (1987) and Cardellichio *et al.* (1988, 1989).

A Short Description of the Model

CGTM utilizes the mathematical programming approach suggested by Samuelson (1952) and incorporated by Kallio *et al.* (1987) in the IIASA forest sector model. A partial equilibrium solution is found by summing consumer plus producer surplus minus transportation costs. Constraints working on the model are (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 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:

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

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).

As 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:

$$P = a(Q/I)^b \qquad (3.1)$$

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:

$$P/P_s = a(Q/U)^b \qquad (3.2)$$

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:

$$I_{t+1} = I_t + G_t - H_t \qquad (4)$$

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.

The Concept of a Spatial Equilibrium

In economic terms, trade linkages between any two (or more) log and commodity (such as lumber and plywood) markets establishes an equilibrium where the amount of logs and commodities supplied by one market is equal to the amount of logs and commodities imported by the second market. In the Pacific Northwest there exist equilibria in *both* the log and commodity markets since trade linkages exist for both of these markets.

What Is an Equilibrium?

To illustrate the economic concept of a market equilibrium consider Figure A1. This figure illustrates a supply and demand curve for lumber in the upper portion, and a supply curve for timber in the lower portion. An equilibrium is defined as the point where the amount supplied is equal to the amount demanded; point **L1** in Figure A1. At equilibrium **P4 - L1** of lumber in log equivalent units is produced at **O - P4** prices. To produce **P4 - L1** of lumber, **PO - TO** of timber is required. The demand for timber then is **PO - TO**, which at equilibrium is supplied at **O - PO** price. Note that for convenience, without affecting our example, we have labeled our quantity axis in log equivalent units to be able to represent the amount of lumber and logs produced and consumed on the same graph.

What is a Global Equilibrium?

How does the market equilibrium portrayed in Figure A1 differ from a global equilibrium? Consider Figure A2. While this figure represents a more complicated process, several important points are illustrated. First, to simplify the problem of illustrating the spatial equilibrium without any loss of information, the figure illustrates the globe (defined here as two markets) where the demand and supply for lumber is drawn in the upper portion, and a timber supply curve is illustrated in the lower portion. Both regions produce both lumber and logs. Second, a global equilibrium point can be defined because the higher price in market B allows lumber to be imported from market A (**P6** is greater than **P4**). A higher log price in market B also allows logs to be imported from market A (**P3** is greater than **PO**), net of transfer costs. The amount of lumber that market A will export to market B will be equal to the amount of lumber demanded in excess of domestic production (**L2 - L3** is equal to **L6 - L4**) in equilibrium. This equilibrium is reached when excess supply from market A is equal to excess demand from market B (**P5 - L5**), illustrated by the intersection of the excess supply and demand curves (heavy lines) in Figure A2. This similar logic--the price differences between markets A and B--leads to an equilibrium in the log markets where the excess supply of logs in market A is equal to the excess demand in market B (**P2 - T4**). From Figure A2 we also note the following. First, prices are higher for the exporter (**P5 > P4**) and lower for the importer (**P5 < P6**) under the spatial equilibrium. Second, log production is higher for the exporting region by an amount **T6 - T8**. This higher production level is comprised of a higher demand to produce more lumber (**T5 - T8**) and export logs (**T6 -**

T5). Lastly, the returns to timber producers are higher (log prices are higher) because of the log exports in market A (**P2** is greater than **P1**). A global equilibrium--commonly referred to as a spatial equilibrium--is the point where the amount supplied by several markets (considered the globe) is equal to the amount demanded by all consumers. This framework provides a convenient method to measure the impacts from a contraction in timber supply (a shift in the timber supply curve) in forest products markets linked through trade of lumber and logs.

Figure A1. Market equilibrium.

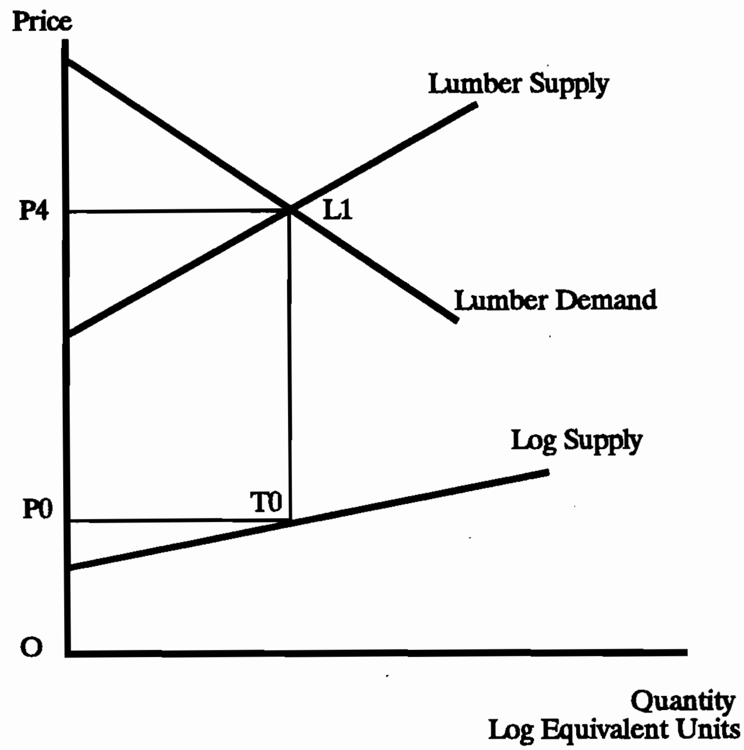
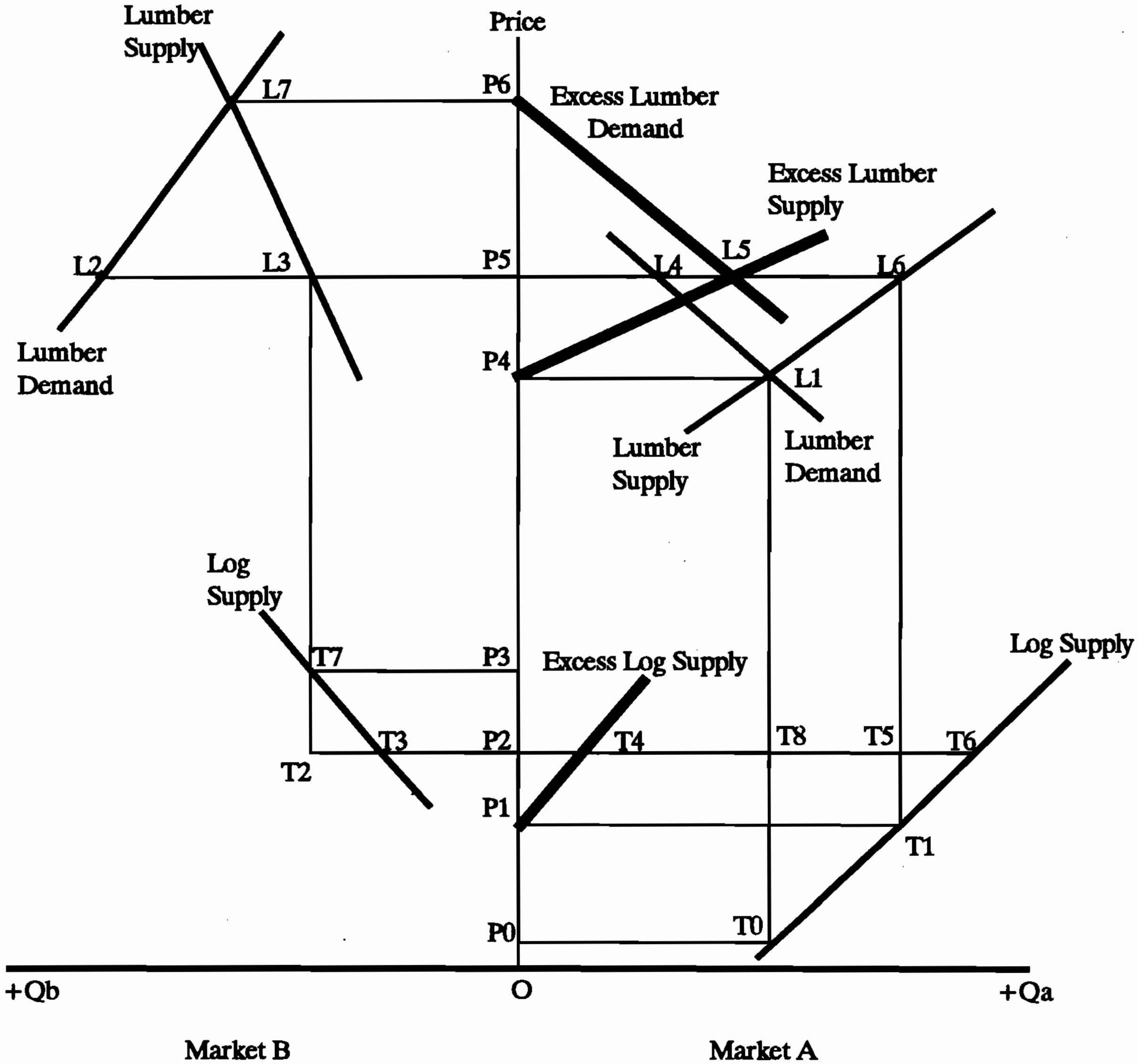


Figure A2. Spatial equilibrium.



LOG MARKET	LUMBER MARKET
O-P1 = Domestic Price in Market A	O-P4 = Domestic Price in Market A
O-P3 = Domestic Price in Market B	O-P6 = Domestic Price in Market B
O-P2 = Equilibrium Log Price	O-P5 = Equilibrium Lumber Price
P2-T6 = Domestic Log Production in Market A	P5-L6 = Domestic Lumber Production in Market A
P2-T3 = Domestic Log Production in Market B	P5-L3 = Domestic Lumber Production in Market B
P2-T5 = Log Demand in Market A	P5-L4 = Lumber Demand in Market A
P2-T2 = Log Demand in Market B	P5-L2 = Lumber Demand in Market B
T5-T6 = Excess Log Supply =	L4-L6 = Excess Lumber Supply =
T2-T3 = Excess Log Demand =	L3-L2 = Excess Lumber Demand =
P2-T4 = Quantity Logs Traded.	P5-L5 = Quantity Lumber Traded.
O-P0 = Closed Market Log Price	P4- L1 = Closed Market Lumber Production.
P0-T0 = Closed Market Log Production.	

Table A1 Timber supply regions in the CGTM

Bold type indicates endogenous regions; * indicates a separate public and private supply region has been specified.

US:
- US West
  - US Pacific Northwest
    - **Westside***
      (Western Washington & Western Oregon)
    - **Eastside***
      (Eastern Washington & Eastern Oregon)
  - **Interior Region***
  - Alaska
  - California Redwood
- **US South**
- **US North**

Canada:
- **BC Coast**
  - **Interior BC**
  - **Eastern Canada**

Central America

South America:
- Brazil
- Rest of North
- **Chile**
- Rest of South

Europe:
- **Finland**
- **Sweden**
- **Rest of Western Europe**
- Rest of Eastern Europe

Asia:
- **Japan**
- **South Korea**
- **Indonesia**
- **East Malaysia**
- **West Malaysia**
- **Papua New Guinea**
- **Philippines**
- China
- Taiwan-Hong Kong
- Indochina
- India
- Middle East

USSR:
- Western USSR
  (Europe and West Siberia)
- Eastern USSR
  (East Siberia and Far East)

Africa:
- North
- East
- South
- West

Oceania:
- Australia
- **New Zealand**
- Rest of Oceania

REFERENCES FOR APPENDIX

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