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Summary

This study reports on market forces and government policies that influence the softwood trade between Japan and North America. The policy environment is described by a lumber import quota in Japan, an embargo on log export in Canada, and free log trade between the United States and Japan. A statistical model measures the influence of log processing and lumber consumption adjustments on the U.S.-Japanese log trade and prices in both countries. The empirical study is based on annual data from the 1960 to 1976 period. Results indicate that Japan's excess demand and the United States' excess supply relations are price responsive in the log market. Mean value elasticities are around −0.2 for Japan and +0.7 for the United States. The finding of a price response on the part of the Japanese stands in contrast to research based on quarterly data from the 1950 to 1969 period and trade unit values instead of wholesale prices. (21.)

The estimates indicate that changes in housing starts and domestic log production in Japan are critical in explaining past and likely future levels of U.S. log trade. Over the 1962 to 1976 period, for example, Japan's increasing construction and declining domestic harvest contributed about equally to rising log purchases from the U.S. During most of the 1980s and 1990s developments in Japan's markets could encourage a log trade near the levels of the mid-1970s. This would be likely if brisk income growth fosters a strong residential construction market and softwood harvests from Japan's forests are comparable to those of the mid-1970s. However, it is possible that Japan could drastically reduce its dependence on U.S. log imports. This might occur if stagnant income precludes strong demand for new housing and the output potential of Japan's softwood forest is realized.

Introduction

The U.S. softwood log trade has fostered a highly publicized controversy that began with export expansions of the mid-1960s. (4, 8, 26). At times, Japan's purchases of timber have approached 10 percent of U.S. production in the highly inelastic softwood market. It's not surprising that lumber users have demanded export restriction or elimination in efforts to reduce domestic prices. On the west coast, where about 25 percent of the timber harvest is shipped abroad, labor interests have been especially vocal. Workers associated with shipping industries have welcomed the employment and income generated by foreign sales, while those in the lumber economy decry the loss of domestic processing.

This paper contains an analysis of the forces affecting the U.S.-Japanese log trade and an assessment of the market forces in Japan that will influence trade in the future. The analysis complements previous work in two respects (21). First, this study emphasizes the structure of Japan's softwood market. Second, the effects of trade policies in Japan, Canada, and the U.S. are also taken into account. The assessment of future trade is limited to measuring the effects of possible expansion in Japan's construction industry and domestic timber supply.

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Japanese North American Trade Policies: A Description

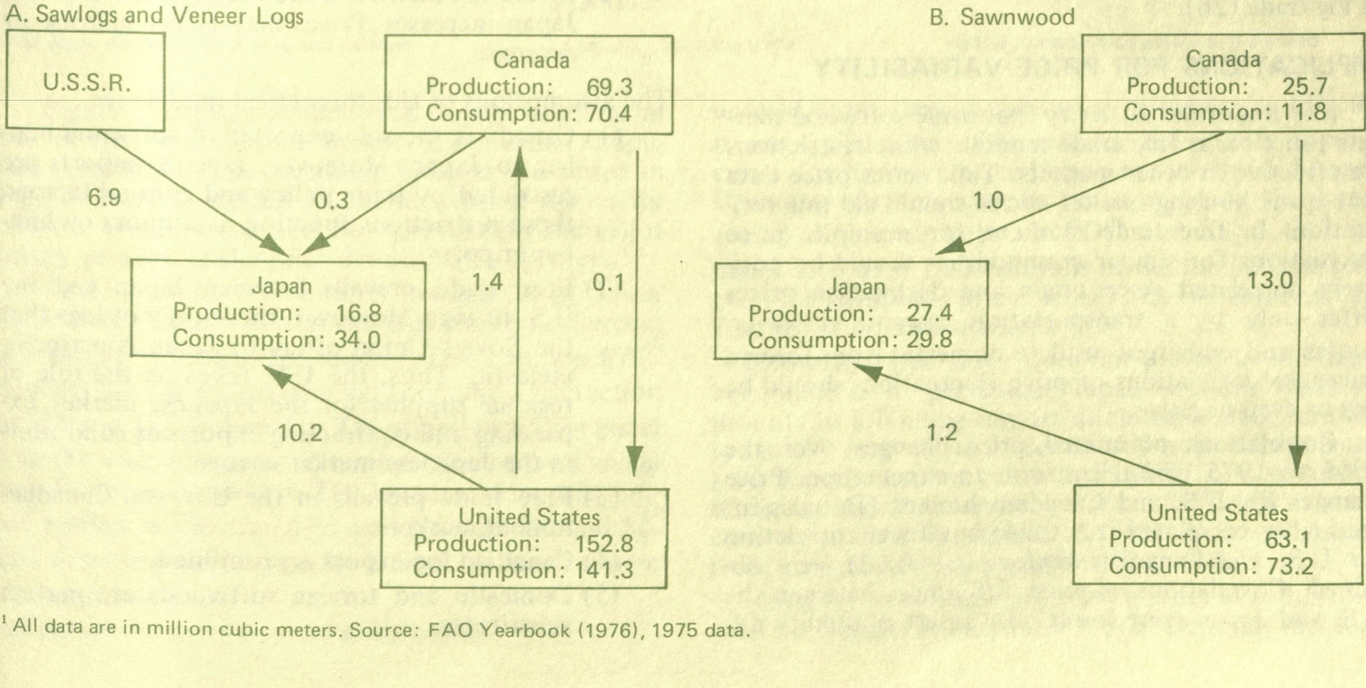
The pattern of trade among Japan, the U.S., and Canada is understandable, provided that comparative advantage and the array of trade restrictions are both taken into account. As a rule of thumb, comparative advantage determines the extent of a country's trade in raw material and processed product while trade policies explain the composition of log and lumber trade. As all three countries have developed labor and capital markets there is no impediment to domestic processing provided that it is profitable. Indeed, most restrictions are attempts to retain domestic processing income by increasing the gap between domestic lumber and log prices. In the case of an importing country like Japan, policies restrict lumber imports thus increasing lumber prices paid by consumers. Canada is the world's leading softwood exporter. Its policies prohibit log exports and reduce log prices paid by processors. In contrast, the United States follows a free trade policy in log and lumber markets. The peculiar U.S. trade pattern – importing lumber from Canada and exporting logs to Japan even though the U.S. is an importing country – is probably a direct result of policies in Japan and Canada.

The comparative advantage yardstick amounts to a comparison of a country's domestic forest resources with population and housing requirements. Japan, an importing country, is characterized by a small land base, a dense population, and a timber resource that was severely depleted during World War II. Consequently, imports expanded beyond half of domestic softwood consumption when construction expanded during the 1960s and early 1970s. But this country is heavily forested and forests replanted after World War II are approaching maturity, so Japan could support domestic consumption levels of the mid-1970s with domestic forests in the near future. Projections of continued dependence in softwood imports hinge on significant demand expansions (6). The U.S. has abundant softwood resources, but not enough to satisfy the massive domestic market; U.S. sawnwood consumption (73 mil m^3) exceeds the combined consumption of Japan (25 mil m^3) and Canada (30 mil m^3). Consequently, the U.S. imports about 25 percent of its softwood from Canada. The timber inventory of the vast Canadian wilderness has about three-fourths the volume of U.S. inventory, but Canada is sparsely populated. Consequently, the Canadians export nearly half of their domestic production to the United States.

Trade flows in log and lumber markets are illustrated in Figure 1. Japan accounts for almost all trade in logs by purchasing 10 mil m^3 from the United States and 7 mil m^3 from the Soviet Union. Small quantities of logs are shipped from the U.S. to Canada (1.4 mil m^3), but almost no logs leave Canada (0.5 percent of Canadian domestic production). U.S. imports from Canada are the major lumber trade (13.0 mil m^3). Minor amounts of sawnwood are also exported from North America to Japan; the U.S. and Canada both ship about one million cubic meters.

The Japanese-North American lumber trade is more limited than Figure 1 indicates. Indeed, subsequent economic analysis builds on the assumption that all U.S. "lumber" exports should be classified as log exports. More than half of North American "lumber" imports (52 percent during the 1968 to 1970 period) are 8 3/4″ or 14″ square timbers that are reprocessed in Japanese mills. Hemlock baby squares (4″) are the major product in the remaining North American sawnwood trade (60 percent during the 1968 to 1970 period) and the Canadians export most

Figure 1. Major trade flows in softwood logs and lumber – Japan, United States and Canada[1].



[1] All data are in million cubic meters. Source: FAO Yearbook (1976), 1975 data.

of these (13). Other data also confirm this hypothesis. For example, the bulk of U.S. lumber exports originate in Alaska (93 percent during 1968-1970) and virtually all Alaskan lumber are squares larger than 4" in thickness.

A number of trade barriers and cultural factors impede trade in Japan's lumber market (6, p. 95). These restrictions add up to a quota, although no such policy is formally stated. First, import of Russian lumber is discouraged by a 10 percent tariff on sawnwood smaller than 160 mm (6.30") in thickness on the major species (spruce, pine, and fir). The major North American species – hemlock and Douglas-fir – are excluded from this tariff, but all imported lumber must be regraded in Japan. The costs of regrading amount to 10 percent of the value of the lumber and 3 percent of this cost is added to the lumber price. A regrading scheme also has the potential to serve as a rationing device when lumber imports exceed a desired level. Finally, Japanese construction methods favor metric lumber sizes. A western (platform/frame) construction method was initiated in recent years and this method is compatible with North American lumber sizes. However, only 0.1 percent of new houses feature this construction method.

The Canadians almost eliminate log exports with a permit system (26). Before a government permit for log export is granted, domestic millers must refuse to buy the timber and the government must approve the log export.

Free trade policies are followed where major U.S. trade occurs. The U.S.-Canadian lumber exchange is a textbook case of free trade. In the log market, the U.S. does not allow export of logs harvested from public lands. Others have argued that this regulation guarantees a supply for domestic processors, but does not inhibit foreign trade. Also, an upper limit has been placed on permissible log exports. The upper limit on exports, however, is beyond observed levels of log trade (26).

IMPLICATIONS FOR PRICE VARIABILITY

It is important to verify that some softwood markets function as free trade markets while restrictions are effective in other markets. Time series price data that spans housing market cycles should aid this verification. In free trade markets, for example, price fluctuations for similar commodities should be positively correlated since origin and destination prices differ only by a transportation margin. However, quotas and embargos insulate domestic from foreign prices, so correlations of price fluctuations should be low or even negative.

Correlations of annual price **changes** over the 1965 to 1975 period conform to expectation. Price changes for U.S. and Canadian lumber (Douglas-fir) are highly correlated ($r = 0.94$) but lower correlation for U.S. and Canadian sawlogs ($r = 0.58$) were obtained. Correlations of price differences between the U.S. and Japan were lower, as a result of quality differences in softwood species and adjustments in U.S.-Japanese exchange rates, but the relative magnitude of log and lumber correlations are as expected. Correlations of log price changes compared U.S. sawlog prices for Douglas fir (expressed in yen) with an index of log wholesale prices for cedar and pine in Japan. The simple correlation between annual price differences is 0.39. Correlations of price changes in the lumber market were based on the Japanese wholesale price for cedar lumber and U.S. Douglas fir prices (expressed in yen). This coefficient is 0.06.

A Model of Price Formation and Trade in Japanese and North American Softwood Markets

The previous discussion of trade policy supports the argument that the log trade between the U.S. and Japan serves as the focal point for all forces affecting two independent lumber markets. Japan does import small quantities of Canadian lumber, but this trade is restricted. Consequently, adjustments in Japan's lumber economy occur without the stabilizing benefits of trade. In the second lumber market, free trade occurs between the U.S. and Canada. The log trade between the U.S. and Japan reflects developments in North American lumber economies on the supply side and Japan's lumber market on the demand side. However, no connection between these two lumber markets exists, unless Japan's trade restriction is relaxed.

This section examines the effects of Japan's trade restriction on prices and trade flows in log and lumber markets. It is shown that the lumber restriction has the following effects:

(1) In the lumber market, Canadian trade with the U.S. increases, but Canadian exports to Japan are reduced. Prices increase in Japan and decrease in North America.

(2) In the log market, trade between the U.S. and Japan increases. Prices may either increase or decrease.

The assumptions of this theoretical model are:

(1) Canada is the sole exporter of softwood lumber to Japan. Moreover, Japan's imports are restricted by trade policy and cultural factors; these restrictions function as a quota on lumber imports.

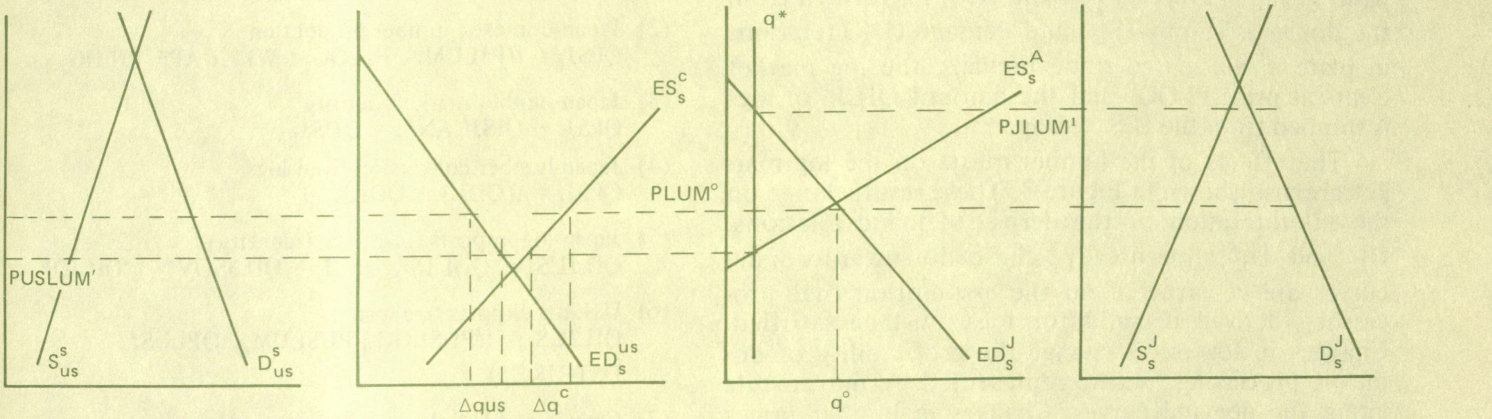
(2) Free trade prevails between Japan and the U.S. in logs. Moreover, the supply of logs that the Soviet Union offers to Japan is perfectly inelastic. Thus, the U.S. takes on the role of residual supplier for the Japanese market, expanding and contracting exports as conditions in the Japanese market change.

(3) Free trade prevails in the U.S. and Canadian lumber market.

(4) Canadian log export is prohibited.

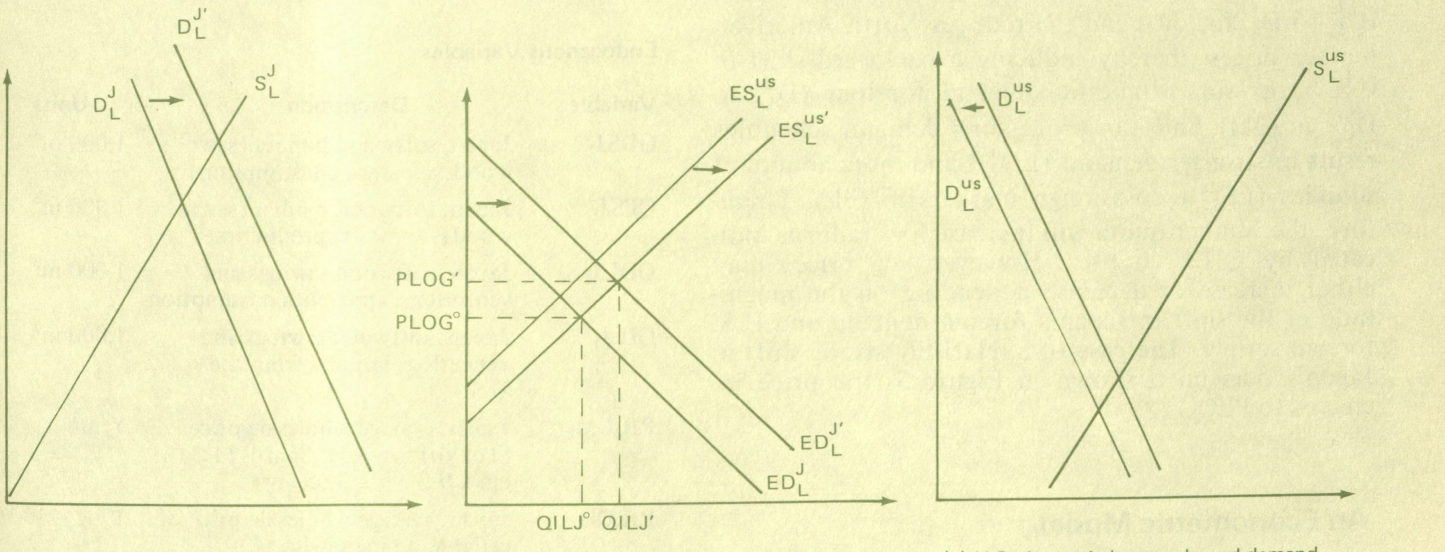
(5) Domestic and foreign softwoods are perfect substitutes.

Figure 2: Price formation and trade in North American and Japanese lumber markets (free trade and quota).



(a) U.S. domestic (b) U.S.-Canada lumber trade (c) Canada-Japan lumber trade (d) Japan domestic lumber

Figure 3: Price formation and trade in the United States and Japanese log markets (free trade and the indirect effects of a lumber quota).



(a) Japan domestic log supply and demand (b) U.S.-Japan log trade (c) U.S. domestic log supply and demand

Figure 2 depicts demand and supply relations in the international lumber markets under rather simplified conditions. The economic linkages illustrated in Figures 2 and 3 are not meant to exhaust the reality of these complex markets but to highlight the major forces at work in the price determination process.[1]

First, consider the lumber markets in isolation. Panel a of Figure 2 shows the U.S. domestic demand and supply functions for lumber. The function ED_s^{us} in panel b is the excess demand formed by interaction of S_s^{us} and D_s^{us} in panel a. The function ES_s^c in panel b is the excess supply of lumber offered by Canada on international markets. The Japanese domestic lumber market is illustrated in panel d with D_s^J and S_s^J. An excess demand relation for lumber by Japan can be derived from these functions as is shown as ED_s^J in panel c. To close this system, the excess supply curve for lumber facing Japan net of the U.S. and Canadian markets can be constructed as the horizontal difference between ED_s^{us} and ES_s^c : ES_s^A in panel c. If free trade prevails in the lumber market, the international price would be established at PLUM° in all three markets.

However, free trade does not prevail in the lumber market. In particular, Japan imposes what amounts to a binding import quota on lumber, shown in panel c as q*. The effect of this trade barrier is to raise Japan's lumber price to PJLUM¹ and to lower Canadian and U.S. lumber prices to PUSLUM'. Canadian trade falls by amount Δq^c but U.S. purchases from Canada increase by Δq^{us} – plate (b).

Now let us introduce the log market into this discussion. Figure 3 illustrates equilibrium in the log

[1] An algebraic treatment is presented in Appendix B.

market. The upward-sloping supply of logs offered by the U.S. (ES_L^{us}) in panel b is derived from the domestic log supply (S_L^{us}) and demand (D_L^{us}) relations in panel c. Japan's foreign demand (ED_L^J) is formed from the domestic supply (S_L^J) and demand (D_L^J) relations in plate a. Since free trade prevails, the log market clears at price PLOG° and the amount QILJ° of logs is shipped from the U.S. to Japan.

The effects of the lumber quota on the log market are also shown in Figure 3. These results hinge on the interpretation of the derived demand relations, D_L^J and D_L^{us}. Specifically, these downward-sloping curves are constructed on the assumption that processors' derived demand for logs must be satisfied. Changes in log prices change the profitability of domestic processing and are represented by movements along the demand curves. Changes in lumber prices also influence the profitability of domestic processing but are represented by shifts in the log demand schedules. Consequently, imposition of the lumber quota: (1) increases Japan's lumber price and causes an outward shift in this processors' demand for logs (D_L^J to $D_L^{J'}$ in (3a)) and (2) reduces North American lumber prices, thereby inducing a backward shift in U.S. processors' domestic demand for logs (D_L^{us} to $D_L^{us'}$ in (3c)). Shifts in processor's demand schedules result in stronger demand ($ED_L^{J'}$) and more abundant supplies ($ES_L^{us'}$) on foreign markets in (3b). Therefore, the lumber quota will increase log trade, as indicated by QILJ′ in (3b). However, log prices may either increase or decrease depending on the magnitude of the shift in Japan's foreign demand and U.S. foreign supply. The case of a relatively strong shift in Japan's demand is shown in Figure 3; the price increases to PLOG′.

An Econometric Model

A. OVERVIEW

This section contains a statistical model of the U.S.-Japanese log trade. It emphasizes the determinants of Japan's foreign demand, but accounts for major adjustments in U.S. and Canadian softwood markets.

Table 1 contains a summary of the relationships in this eight-equation model.

Japan's market is described by three estimated relationships. The lumber demand equation (1) measures the adjustments of lumber consumers to changes in lumber price and new housing starts. The lumber production response function (equation 2) shows processors' reaction to changes in log and lumber prices, wages and capacity. Equation (4) measures the conversion of logs to lumber. Japan's log import demand schedule is the result of combining these estimated relations with market clearing identities for lumber (equation 3) and logs (equation 5).

Table 1[2]

(1) Japan-domestic lumber consumption
$QDSJ_t = f(PJLUM_t ; HSJR_t^*, HSJNR_t^*)$

(2) Japan-domestic lumber production
$QPSJ_t = f(PJLUM_t , PJLOG_t ; WJ_t^*, CAP_t^*, PJLOG_{t-1})$

(3) Japan-lumber market identity
$QPSJ_t + QISJCAN^*_t = QDSJ_t$

(4) Japan-lumber conversion from logs
$QPSJ_t = f(QDLJ_t ; QDLJ_{t-1})$

(5) Japan-log imports from U.S. (identity)
$QILJUS_t = QDLJ_t - QPLJ_t - QILJSOV^* - QILJO^*$

(6) U.S.-log exports to Japan
$QILJUS_t = f(PUSLOG_t, PUSLUM_t ; QPLUS_t^*, DSTRIKE_t^*)$

(7) Canada and U.S.-log-lumber price relationship
$PUSLUM_t = f(PLOG_t ; HSUS_t^*, HSCAN_t^*, QPLCAN_t^*, QISJCAN_t^*)$

(8) U.S. and Japan-log price linkage
$PJLOG_t = f(PUSLOG_t ; EX_t^*)$

Endogenous Variables

Variable	Description	Units
$QDSJ_t$	Japan, softwood lumber (sawnwood, apparent consumption)	1,000 m^3
$QPSJ_t$	Japan, softwood lumber (sawnwood), domestic production	1,000 m^3
$QDLJ_t$	Japan, softwood sawlogs and veneerlogs, apparent consumption	1,000 m^3
$QILJ_t$	Japan, softwood sawlogs and veneerlogs imports from the U.S.	1,000 m^3
$PJLUM_t$	Japan, average wholesale price (Tokyo) for cedar boards (1.3 cm x 9.0 cm x 3.65 cm)	Y/m^3
$PJLOG_t$	Japan, average wholesale price of cedar and pine sawlogs	1962 = 100.0
$PUSLUM_t$	United States, wholesale price of Douglas fir lumber 25 percent std and btr, 2″ x 4″ random lengths, f.o.b. mill	\$/m.b.f.
$PUSLOG_t$	Douglas fir sawmill log prices, western Washington and northwestern Oregon	\$/m.b.f.

Exogenous Variables

Variable	Description	Units
$HSJR_t$	Japan, building starts, residential	mill m^2
$HSJNR_t$	Japan, building starts, nonresidential	mill m^2
$HSUS_t$	United States, housing starts	1,000 units
$HSCAN_t$	Canada, housing starts	1,000 units

[2] Data values and sources are given in the appendix.

Table 1[2] *(Continued)*

Exogenous Variables

Variable	Description	Units
$QPLJ_t$	Japan, softwood sawlogs and veneerlogs, domestic production	1,000 m^3
$QPLUS_t$	United States, softwood sawlogs and veneerlogs, domestic production	1,000 m^3
$QPLCAN_t$	Canada, softwood sawlogs and veneerlogs, domestic production	1,000 m^3
$QISJCAN_t$	Japan, quantity of softwood lumber imported from Canada	1,000 m^3
$QILJSOV_t$	Japan, quantity of softwood sawlogs and veneerlogs imported from the Soviet Union	1,000 m^3
$QILJO_t$	Japan, quantity of softwood sawlogs and veneerlogs imported from countries other than the U.S. or U.S.S.R.	1,000 m^3
WJ	Japan, average monthly cash earnings of regular workers in the lumber and wood products industry	1,000 ¥
CAP	Japan, a capacity index for the softwood lumber industry	1970 = 1.0
EX	Japan and U.S., exchange rate	¥/$
WPIUS	U.S., index of wholesale prices	1967 = 100.0
DSTRIKE	A dummy variable which accounts for the trade effects of the 1971 West Coast dock strike (=1.0 in 1971 and - 1.0 in 1972 and 0.0 otherwise)	

The more modest intentions for the North American supply side are to: (1) measure U.S. processor's adjustments to changing log prices, and (2) account for the fact that U.S. log processing adjustments alter the U.S.-Canadian trade which, in turn, causes adjustment in the North American lumber price. Accordingly, the foreign log supply relation (equation 6) is estimated directly. This equation measures U.S. processors' adjustment to changing log and lumber prices with given log production. A second behavioral equation (7) describes the relation between North American log and lumber prices. The equation builds on the assumption of equilibrium in the U.S.-Canadian lumber trade and accounts for the Canadian log embargo.

Equation 8 postulates a close relationship between U.S. and Japanese log prices. This equation builds on the assumption of free trade in the log market.

Log supplies are taken as perfectly inelastic (exogenous) in all three countries. It is reasonable that log supplies are positively related to price in the longest run of our theoretical exercise (Figure 3); a sustained price increase, for example, calls for output increases, at least with longer rotations on a given land base and may also induce an investment in more land used for log production. A thorough econometric analysis, however, must deal with several other problems such as: the short-run economic problem of marketing mature timber (27), the forces affecting investment in future timber capacity (reforestation), and the rules governing management of public forest lands. Such an analysis is beyond the scope of this investigation.

B. JAPAN

In general, straightforward application of standard production and demand theory, guided by other applications to forest product markets yielded satisfactory results.

Domestic supply response estimates follow from standard production theory. In general, output depends on output price, input prices for variable factors, and quantities of fixed inputs (11). In most forest product applications, logs (stumpage) and labor are taken as variable factors while processors capital stock is fixed (1, 2, 22).

Estimates of Japan's producer response follow this general prescription, but it's necessary to be aware of the unique features of Japan's wood processing industry. First, Japan's processing capacity expanded rapidly during the 1960s and no suitable capital measure was available. Thus, a capacity index was developed with Klein's "trend through peaks" method. Second, colinearity among wage, lumber, and log price data made estimation of reliable coefficients difficult. In preliminary regressions, all three coefficients had the correct sign, but the lumber price response was "small" relative to input price elasticities.[3] Accordingly, input prices were combined to form an input price index.

The "best" set of weights on wages and the log price index was obtained by minimizing the sum of squared errors. The following equation, estimated with least squares, was the best of several similar specifications:

$$(1)\ QPSJ = -7{,}232.2147 + \underset{(3.38)}{0.22183533} PJLUM_t - \underset{(2.77)}{}$$

$$\underset{(4.56)}{38.392390}\, PI_t + \underset{(15.84)}{40{,}792.370}\, CAP_t$$

$$R^2 = 0.954 \qquad D.W. = 1.06 \qquad \bar{S} = 862.86$$

[3] Because the marginal products of variable inputs are equated to input-product price ratios under profit maximization, supply functions are homogenous of degree zero in product and variable input prices (12). Consequently, an elasticity constraint defines appropriate sizes for product and input price elasticities.

$$e_{Q.P} = -\sum_{i=1}^{n} e_{Q.P_i}, \text{ where}$$

$e_{Q.P}$ = the elasticity of output (Q) with respect to the price of output (P)

$e_{Q.P_i}$ = the elasticity of output (Q) with respect to the price of the i th variable input (P_i).

In preliminary regressions the log price elasticity exceeded the lumber price elasticity.

where

CAP = a capacity index

CAP = (−53,532.625 + 1246.125T)/32,750; if $T \leqslant 70$

1 if $T \geqslant 70$

note: QPSJ (1970) = 32,750

PI = a price index for variable cost items (1962 = 100)

$$= 0.625 \cdot PJLOG + 0.375 \frac{\cdot WJ}{198}$$

Dependent variable mean: 28,058
Historical period: 1960 to 1976

Lumber demand originates in the construction industry. Thus lumber consumption should depend on prices of lumber, substitute inputs, and output (*i.e.*, housing or non-residential construction prices). Empirical studies of lumber consumption typically relate consumption to prices of substitute inputs. However, output quantity measures (building starts) are usually used instead of building price. Additionally, some investigations account for the different lumber requirements of commercial and residential construction by the use of such variables as separate residential and non-residential construction or ratios of these variables.

Attention to characteristics of Japan's market should enhance the analysis of lumber consumption. First, it is plausible low quality hardwoods (luan) and non-wooden building methods both substitute for softwood in buildings. Second, the composition of Japan's building activity switched during the mid-1960s. In the early 1960s most building was intended for non-residential use but later credit for residential construction was more plentiful and building favored residential construction. Accordingly, one should account for the effect of this change in building composition on lumber consumption.

Several sets of explanatory variables for explaining historical variation in "apparent consumption" were considered. Experiments involved comparison of nominal and real prices, alternative responses to residential and non-residential construction, and tests for substitutions between hardwood and softwood lumber consumption. Regressions with real prices had lower explained variations than analogous specifications with nominal prices. Also, when luan lumber prices were included, coefficients estimates were small relative to standard errors. It is difficult to conclude that this substitution does not exist, since the simple correlation between cedar and luan lumber prices was around 0.96. Colinearity problems also precluded measurement of separate lumber responses to residential and non-residential construction. However, regressions with total building starts and the proportion of residential to total construction yielded reasonable results.

Equation 2 below was the best of these formulations:

$$(2)\ QDSJ_t = 12{,}468.047 - 0.2850614PJLUM_t + \underset{(1.65)}{} \quad \underset{(3.02)\ -0.28}{}$$

$$84.24076HST + 21{,}974.600\ HSR$$
$$(7.08) \qquad (1.232)$$
$$+0.45 \qquad 0.39$$

$R^2 = 0.8238$ D.W. = 0.8693 $\bar{S} = 1{,}840.69$

where

HST = HSJR + HSJNR

$$HSR = \frac{HSJR}{HSJR + HSJRNR}$$

Dependent variable mean: 28,880.67
Historical period: 1960 to 1976

Most statistical properties are acceptable. Coefficient estimates have correct signs and t ratios indicate significance or a contribution to explaining historical variation. Also, a high proportion (82 percent) of consumption variation is explained. However, the Durbin Watson Statistic suggests that unexplained variation may not be due to random elements. Several possibilities for excluded systematic effects exist. First, the pattern of residuals switched from positive to negative in the mid-1960s and this change corresponded to a new composition in residential and non-residential building. Thus, it is possible that some structural change occurred at this time. Second, the influence of lumber inventories is buried in apparent consumption data, so cyclical inventory adjustments could account for the residual pattern.

The relation between log and lumber markets is given by a simple regression of sawnwood production on apparent sawlog consumption. This approach is justified on the grounds that there is a fixed rate of conversion between logs and lumber. The exact specification presented here employs current and lagged values of sawlog consumption, since it is likely that imported sawlogs are not processed until a later date. When lagged log consumption was included with current consumption, R^2 improved slightly, but the sum of current and lagged coefficients remained fixed around 0.85. Equation 3 below shows the results:

$$(3)\ QPSJ_t = -2{,}766.0964 + 0.60467347QDL_t +$$
$$(1.31) \qquad (6.52)$$

$$0.24336772QDL_{t-1}$$
$$(3.01)$$

$R^2 = 0.942$ D.W. = 1.16 S = 840.41

Dependent variable mean: 28,884.87
Historical period: 1962 to 1976

B. THE UNITED STATES

The U.S. excess supply of logs is, by definition, the difference between domestic supply and demand.

In general then, log exports can be expressed in terms of variables that influence domestic supply and demand functions. In the statistical analysis of U.S. log exports, domestic log supply is taken as given. Processors' log demands depend on log and lumber prices, wages and processing capital.

Preliminary estimates showed that real prices explained more of the historical variation in exports than similar regressions with nominal prices and that wage rates were not significant explanatory variables. Additionally, it seems that the prolonged west coast dock strike in 1971 had a substantial effect on U.S. log exports. This finding has been confirmed in other studies of trade between the U.S. and Japan (7). Accordingly, a dummy variable has been included to account for the effect of the dock strike. Equation 4 below shows the results of estimation:

$$(4)\quad QILJUS_t = \underset{(3.30)}{-24{,}716.578} + \underset{\substack{(3.73)\\ 1.22}}{9{,}736.503}\frac{PUSLOG_t}{WPIUS_t} - \underset{\substack{(1.04)\\ -0.69}}{6{,}380.166}\frac{PUSLUM_t}{WPIUS_t} + \underset{\substack{(3.04)\\ 3.77}}{0.17873}QPLUS_t - \underset{(1.95)}{2{,}424.94}DSTRIKE_t$$

$R^2 = 0.793$ D.W. = 1.51 $\bar{S} = 1{,}590$

Dependent variable mean: 7,490.9
Historical period: 1962 to 1976

C. EQUILIBRIUM IN U.S. AND CANADIAN LUMBER TRADE

Much empirical analysis of price behavior begins with the notion that supply (or cost) and demand (capacity utilization) forces both to play a role in market pricing.[4] This principle is applied to the problem of estimating the relationship between log and lumber prices for North America. The basic building blocks for the price equation are: (1) lumber supply and demand relationships in Canada and the U.S.; (2) the assumption of free trade between the U.S. and Canada in lumber; and (3) an embargo on log trade between the U.S. and Canada. A linear relationship is developed with the North American lumber price as the dependent variable and the price of logs, housing starts in the U.S. and Canada, Canadian log production, and the quantity of Canadian lumber shipped to Japan as independent variables. This relationship is applied to time series data for the 1960s and early 1970s.

Suppose that: (1) U.S. and Canadian processors face the same lumber price (PUSLUM) but (2) Canadian log export embargo drives a wedge between U.S. log price (PUSLOG) and Canadian log prices (PCNLOG). The lumber production (QPSUS), consumption (QDSUS), and import (ICN^D) relations of the U.S. market are:

(i) $QPSUS_t = \alpha_1^1 + \beta_1^1\, PUSLUM_t - \gamma_1^1\, PUSLOG_t$

(ii) $QDSUS_t = \alpha_2^1 - \beta_2^1\, PUSLUM_t + \gamma_2^1\, HSUS_t$

(iii) $ICN_t^D = QDSUS_t - QPSUS_t$

Similar production (QPSCN), consumption (QDSCN) and import supply (ICN^S) relations are given for the Canadian market:

(iv) $QPSCN_t = \alpha_1^2 + \beta_1^2\, PUSLUM_t - \gamma_1^2\, PCNLOG_t$

(v) $QDSCN_t = \alpha_2^2 - \beta_2^2\, PUSLUM_t + \gamma_2^2\, HSCN_t$

(vi) $ICN_t^S = QPSCN_t - QDSCN_t - QISJCAN^*$

where QISJCAN* is the level of Japanese imports. Since the Canadians embargo log export, domestic log consumption is equal to production. Given that log supplies are assumed to be perfectly inelastic, Canadian lumber production is determined by log production. Thus equation (iv) can be rewritten as:

(iv)′ $QPSCN_t = \alpha QPLCN_t$,

where $QPLCN_t$ = Canadian sawlog production.

The lumber market equilibrium price relation is obtained by developing lumber import supply and demand functions, assuming that trade equilibrium occurs, so that an expression that does not contain lumber trade can be developed, and rearranging. The U.S. import supply is obtained by substituting (i) and (ii) into (iii) to yield:

(vii) $ICN_t^D = (\alpha_2^1 - \alpha_1^1) - (\beta_1^1 + \beta_2^1)\, PUSLUM_t + \gamma_1^1\, PUSLOG_t + \gamma_2^1\, HSUS_t$

Similarly the Canadian excess supply function results from substituting (iv′) and (v) into (vi):

(viii) $ICN_t^S = -\alpha_2^2 + \alpha_2\, QPLCN_t + \beta_2^2\, PUSLUM_t - \gamma_2^2\, HSCN_t - QISJCAN_t^*$

Assuming trade equilibrium ($ICN_t^S = ICN^D$), (vii) and (viii) can be combined to obtain

$$(ix)\quad PUSLUM_t = K + \frac{\gamma_1^1}{S_{12}} PUSLOG_t + \frac{\gamma_2^1}{S_{12}} HSUS_t - \frac{\alpha_2}{S_{12}} QPLCN_t + \frac{\gamma_2^2}{S_{12}} HSCN_t + \frac{1}{S_{12}} QISJCAN_t$$

where $S_{12} = \beta_1^1 + \beta_2^1 + \beta_2^2$

Equation (ix) gives the theoretical basis for analyzing log-lumber price relationships. The relation suggests that, sans shifts in market conditions, log and lumber prices should be positively related. Furthermore, given log prices, lumber price should increase with demand expansions in either country (HSUS and HSCN) or supply restrictions in Canadian markets (reductions in QPLCN or increases in QISJCAN*).

Estimates of this price relationship yielded satisfactory results. In equation (5) all coefficient estimates have correct sign, t-values for the explanatory variables indicate significance or contribute to explained variation and a high proportion of historical variation is explained:

[4] Nordhaus provides a review of some of this literature (20, pp. 34-42).

(5) $PUSLUM = 24.6604 + \underset{(8.29)}{0.57281}\, PUSLOG_t +$

$\underset{(2.70)}{0.0230475}\, HSUS_t + \underset{(1.20)}{0.130093}\, HSCAN_t$

$+ \underset{(1.09)}{0.008348}\, QISJCAN_t - \underset{(2.78)}{0.000947395}\, QPLCAN_t$

$R^2 = .9786$ D.W. = 2.39 $\bar{S} = 5.15$

Dependent variable mean: 98.179
Historical period: 1962 to 1976

E. U.S.-JAPAN LOG PRICE LINKAGE

Because of the free log trade, price differences between Japan and the U.S. should only reflect transportation charges, exchange rates, and quality differentials. This close relationship is approximated by a regression of Japan's log price on the yen equivalent of the U.S. price:

(6) $PJLOG_t = \underset{(3.91)}{26.748259} +$

$\underset{(19.19)}{0.0032257362}\, (PUSLOG \cdot EX)$

$R^2 = 0.963$ D.W. = 1.64 $\bar{S} = 9.88$

Dependent variable mean: 148.56
Historical period: 1962 to 1976

Impact Multipliers

Multipliers measure the overall effect of changes that occur outside the softwood market (19). For example, the single equation analysis of the previous section demonstrated that an increase in Japan's construction encourages domestic lumber consumption. Multipliers provide a method of accounting for a series of secondary effects. In the example, expansions in domestic lumber consumption are accompanied by higher lumber prices and production. In turn, log prices are bid up and the U.S. provides more logs to Japan at the higher price. Higher lumber prices would also occur in North America because logs are diverted from domestic markets.

The multiplier estimates of Table 2 are based on the statistical relationships of the previous section. An initial price and trade equilibrium is represented by solving equations (1) through (8) for a given level of exogenous variables. A second equilibrium level is then computed for the case where one exogenous variable is slightly larger than in the first solution. The impact of this exogenous change is then computed as the difference between the two solutions of endogenous variables. The major exogenous variables are tabulated on the rows of Table 2. The effects of changes in domestic log production and housing starts in all three trading countries, along with Japan's lumber quota and the terms of trade between Japan and the U.S. are shown. The corresponding endogenous variable changes are tabulated in Table 2. The effects on log trade, log and lumber prices in Japan and North America, as well as Japan's domestic lumber production and consumption are tabulated.

It should be noted that these estimates reflect processors adjustments to changing log and lumber prices, *i.e.*, log supplies are taken as perfectly inelastic in all three trading countries. To the extent that there is a positive relation between log production and price, these estimates place limits on actual responses. In particular, price adjustments would be upper limit estimates and quantity adjustments would be lower limit estimates.

Table 2. Impact multipliers – 1972 base solution.

Exogenous variable	Units	1972 value	Change		QDLJ	QILJUS	PUSLOG	PUSLUM	PJLOG	QPSJ	QDSJ	PJLUM
				Units	1,000 m^3	1,000 m^3	\$/ m.b.f.	\$/ m.b.f.	1962=100	1,000 m^3	1,000 m^3	y/m^3
				value 1972	42,187.0	11,187.0	119.1	117.48	144.0	32,344.0	33,309	33,958.0
QISJCAN	1,000 m^3	965.0	1.0		–.5001	–.5001	–.0010	.0078	–.0010	–.4241	.5729	–2.0202
QILJSOV	1,000 m^3	6801.0	1.0		.2334	–.7666	–.0150	–.0086	–.0147	.1980	.1980	–.6942
QPLJ	1,000 m^3	21,789.0	1.0		.2334	–.7666	–.0150	–.0086	–.0147	.1980	.1980	–.6942
QPLUS	1,000 m^3	162,839.0	1.0		.0417	.0417	–.0027	–.0015	–.0026	.0354	.0354	–.1241
QPLCAN	1,000 m^3	76,327.0	1.0		.0118	.0118	–.0008	–.0014	–.0007	.0100	.0100	–.0352
HSJR	mill m^2	134.707	1.0		49.195	49.195	.964	.552	.943	41.723	41.723	290.08
HSJNR	mill m^2	109.132	1.0		13.714	13.714	.268	.154	.262	11.628	11.628	80.784
HSUS	1,000 units	2378.0	1.0		–.2879	–.2879	.0185	.0337	.0181	–.2443	–.2443	.8565
HSCAN	1,000 units	249.9	1.0		–1.625	–1.625	.105	.190	.102	–1.379	–1.379	4.834
WJ	1,000 Yen/mo	75.7	1.0		–36.965	–36.965	–.724	–.414	–.707	–31.345	–31.345	+109.97
EX	Yen/\$	303.100	1.0		–5.195	–5.195	–.102	–.058	.326	–4.405	–4.405	15.456

A. THE NATURE OF ADJUSTMENTS TO CHANGES IN JAPAN'S MARKET CONDITIONS

Several characteristics of price and trade adjustments are noteworthy, as past response to changes in policy and underlying economic conditions provide the best yardstick for gauging future adjustments. In view of the emphasis in the empirical study, the discussion is limited to changes originating in Japan.

The estimates of price adjustment to changes in log market supply are consistent with other forestry economics research in that log price adjustments exceed lumber price adjustments (9). For example, the estimates for an increase in Japan's log production (QPLJ) in elasticity form show that a 1 percent increase in production causes log and lumber price changes of -2.23 percent and -0.45 percent, respectively, in Japan. Similarly, log and lumber prices drop by 2.75 percent and 1.60 percent in North America.

Adjustments to increases in Japan's domestic log production take the form of reduced U.S. imports and higher domestic consumption. These results indicate that most of the adjustments come in the form of reduced log trade. From row 3 of the table, a production increase of 1 million m^3 (QPLJ) is followed by a 0.2333 million m^3 increase in domestic consumption (QDLJ) and a .767 million m^3 drop in log imports from the U.S. (QILJUS).

Increases in Japan's residential construction (HSJR) induce increases in all endogenous variables. Since lumber production response in Japan is not perfectly elastic, it is understandable that only part of the initial demand expansion is transferred to increased log imports. The relation between building starts and lumber consumption (equation 2 of the previous section) suggests that a typical house (85 m^2 of floor area) requires about 10.5 m^3 of lumber.[5] The relationship between housing starts and log imports (Table 2) corresponds to a log import expansion of 4.2 m^3 for each additional house. Thus slightly less than half of the initial demand expansion transfers to the market for imported logs.

Following the Tokyo round of GATT negotiations it is also possible that increasing amounts of lumber will enter Japan's lumber market directly (8). The estimates of Table 2 indicate the effects of lumber trade liberalization for the assumption that the U.S. remains active only in the log and semi-processed markets. A 1.0 million m^3 increase in Canadian lumber imports (QISJCAN) is split almost equally between an expansion in domestic consumption (QDSJ) of .573 mill m^3 and a reduction in domestic lumber production (QPSJ) of .424 mill m^3. Reduced domestic processing implies a .5 mill m^3 drop in domestic log consumption and imports from the U.S. (QILJ). Japanese lumber prices (PJLUM) fall (2020.2 Y/M^3 or 6 percent) due to more plentiful supply while North American lumber prices (PUSLUM) rise ($7.81/m.b.f. or 6 percent) due to lumber supplies diverted from North American markets. Finally, log prices would fall slightly (1 percent) because the shift in Japanese demand exceeds the log supply shift in North America resulting from higher lumber prices.

[5] This estimate conforms with calculations of wood requirements. A wooden house takes about 16 m^3 of lumber while steel frame construction requires about 4.0 m^3 per unit (24). In 1972 about 70 percent of all houses were wooden.

B. WHY DID JAPAN'S LOG IMPORTS EXPAND DURING THE 1960s AND EARLY 1970s?

Analysts who are familiar with the log trade are aware that the import expansion coincided with increasing construction activity, falling domestic production, and more favorable terms of trade between Japan and the U.S. One factor that might have partially offset this trend was the gradual expansion of Canadian lumber exports to Japan. The multipliers provide an indication of how important each of these factors were, since the change in log imports between any two years can be written in terms of multipliers and the corresponding changes in exogenous variables:

$$\Delta QILJUS = \bar{.}7666\,\Delta QPLJ + 49.195\,\Delta HSJR + 13.714\,\Delta HSJNR - 5.195\,\Delta EX - .5001\,\Delta QISJCAN + R$$

where R is a residual accounting for North American supply shifts and random effects and Δ indicates a change in the corresponding variable.

The contribution of various factors to the change in log imports between 1962 and 1976 can be calculated by noting the changes occurring over this time:

$$\Delta QILJUS = 9{,}410.0\ (1.000\ m^3)$$
$$\Delta QPLJ - 8{,}076.0\ (1.000\ m^3)$$
$$\Delta HSJR = 98.307\ (1{,}000{,}000\ m^2 \text{ floor area})$$
$$\Delta HSJNR = 43.4\ (1{,}000{,}000\ m^2 \text{ floor area})$$
$$\Delta EX = -63.65\ (\text{Yen/dollar})$$
$$\Delta QISJCAN = 1{,}081.0\ (1{,}000\ m^3)$$

Upon multiplying changes in exogenous variables by coefficients and expressing the import change in percentage terms, the following decomposition results:

total trade expansion		reduced domestic production		increased construction		dollar devaluation		less restrictive lumber trade		N.A. supply & random effects
(100 percent)	=	(66 percent)	+	(58 percent)	+	(4 percent)	–	(6 percent)	–	(22 percent)

Possible Developments in Japan's Market Conditions and Implications for U.S. Softwood Markets

Future trade balances depend critically on construction activity and domestic softwood harvest in Japan. Reasonable scenarios for the next 20 years range from stagnant markets for new housing and abundant timber harvests to strong construction markets and forest output near the low levels of the 1970s. This section contains a discussion of factors that are likely to influence construction and timber harvest. Estimates of reasonable bounds also are presented. Housing start projections are based on previous research (24), while speculations on future roundwood output are based on a crude inventory growth model for Japan's privately-owned forest. The scenarios suggest that, at best, U.S. log trade will show a slight, gradual decline over the next 20 years. On the other hand, Japan could stop importing logs from the U.S. by 1990.

A. ROUNDWOOD OUTPUT

Discussions of long-run harvest potential start with the Japan Forestry Agency's position that by the year 2020, domestic roundwood production will be about 2.5 times the levels of the mid-1970s (14). North American opinion seems to doubt the full magnitude of this production increase, but not the fact that it will occur (6, 25). The North American outlook for the interim and the species-composition of future supplies seems less certain. One author has stated that the "trough has been reached and that within the next five years harvest from the domestic forest in Japan will increase." Less has been said, however, about the factors that could influence the magnitude, timing, and species composition of these output increases over the next few decades.

My intention is to present a preliminary discussion of softwood output potential for the interim period (prior to 2010) based on a rather casual interpretation of the available Japanese data. First, some important characteristics of Japan's post war reforestation are discussed. Then some plausible softwood harvest scenarios for the next few decades are presented. Finally, I comment on some economic forces that could influence timber harvest schedules. In particular, it is argued that future output potential will favor softwood at the expense of hardwoods. Also, Japan's softwood production could work to displace imports by the early 1990s at the lower end of plausible harvest ages. Finally, stand ages could depend on price prospects, with falling prices encouraging early harvest and rising prices favoring the harvest of more mature timber.

1. History and Situation

Japan's "artificial" forests are the source of future production potential. These forests are planted with selectively bred seedlings, fertilized, and periodically thinned. In 1976, these forests comprised about 40 percent of Japan's forest area and contained about 35 percent of national inventory volume. Virtually all of this forest is planted to softwood and the bulk of this land is privately owned; 1975 data indicate that the privately owned artificial forest accounts for 30 percent of Japan's total forest area.

Historical data also indicate that Japan's investment in artificial softwood forests has come at the expense of natural forest and future hardwood supply potential. During the 1962 to 1976 period, the total forest area has remained constant at about 25 million hectares. However, artificial forests increased by 2.3 million hectares and natural forests declined by an equal amount over the same period (Figure 4). Afforestation and cut data also confirm this tendency. During the 1972 to 1977 period, about 85 percent of the reforested area was planted to artificial softwood forests. Meanwhile, 80 percent of clear cut area was natural hardwood forest.

Figure 4. Forest area in Japan, by type, 1962-1974.

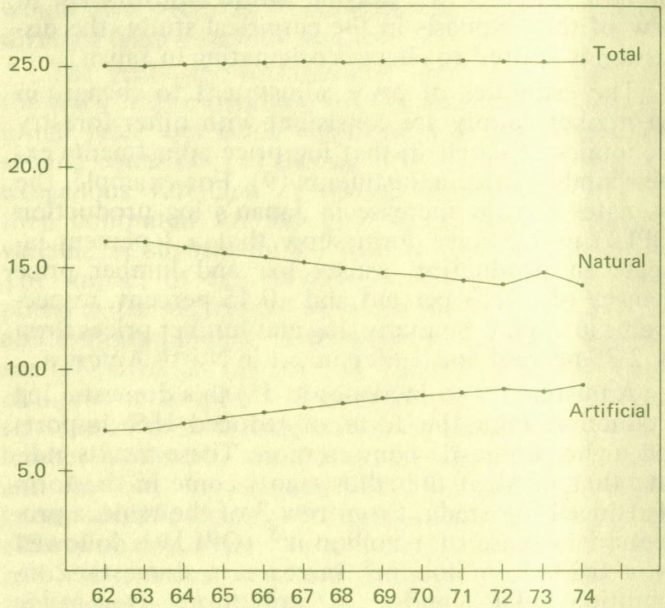


Figure 5. Age distribution of non-national, artificial forest in 1975.

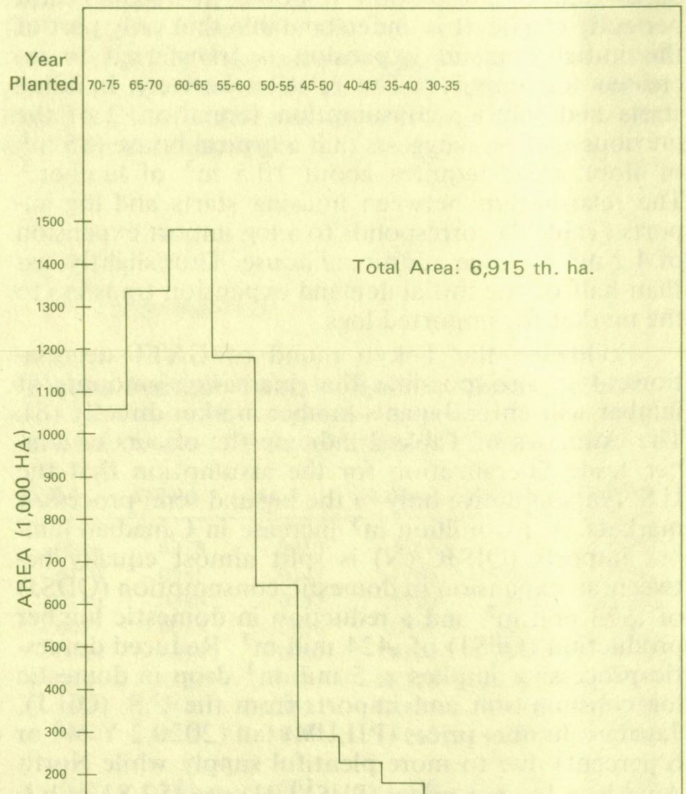


Table 3. Japan's softwood roundwood production – actual (1975) and projected (1975-2000).

Actual	National forest land	Million cubic meters harvested from non-national forest lands								Total			
1975	3.099	17.77								20.86			
		Natural				Artificial							
Projected		35 Yr.	40 Yr.	45 Yr.	50 Yr.	35 Yr.	40 Yr.	45 Yr.	50 Yr.	35 Yr.	40 Yr.	45 Yr.	50 Yr.
1975-80	3.10	4.05	7.73	10.54	12.16	16.81	13.13	10.32	8.70	20.86	20.86	20.86	20.86
1981-85	3.10	4.05	7.73	10.54	12.16	21.46	16.81	13.13	10.32	25.51	24.54	23.76	22.48
1986-90	3.10	4.05	7.73	10.54	12.16	47.71	21.46	16.81	13.32	51.76	29.19	27.35	25.29
1991-95	3.10	4.05	7.73	10.54	12.16	88.19	47.71	21.46	16.81	92.24	55.44	32.0	28.97
1996-2000	3.10	4.05	7.73	10.54	12.16	109.43	88.19	47.71	21.46	113.48	95.92	58.25	33.62
2001-05	3.10	4.05	7.73	10.54	12.16	98.15	109.43	88.19	47.71	102.2	117.16	98.73	59.87
2006-10	3.10	4.05	7.73	10.54	12.16	77.87	98.15	109.43	88.19	81.92	105.88	119.97	100.3

The private and local government investment in artificial softwood forests is primarily a post-war phenomena (Figure 5). Area planted before World War II had timber that was at least 36 years old in 1975. This area comprises a modest 10 percent of the non-national, artificial forest area. Large investment began during the 1950s and early 1960s, a period of increasing consumption and heavy domestic production. Timber between 11 and 25 years old accounts for 47.9 percent of the forest area. Substantial investments continued during the import expansion period (1965 to 1975). Timber in the 6-10 year age group accounts for about 35 percent of the area.

2. Prospects

The prospects for increasing supplies during the next few decades hinge on future replanting activity. If the present conversions from hardwoods to softwoods cease, the longest run softwood supply prospects will discourage heavy cutting from the artificial forest that was less than 25 years old in 1975. If the conversion to softwood forests continues, though, it is likely that the area with forests presently less than 25 years old will be harvested as it nears maturity. Furthermore, plausible softwood rotations are between 35 and 50 years (15). Consequently, dramatic harvest expansion could begin in the late 1980s. I assume that conversions to softwood will continue. The estimates emphasize potential developments of artificial forests. Thus, future roundwood production from natural and nationally owned forests are assumed to remain near 1975 levels.

Future roundwood production on artificial forests is computed as the product of stand/yield and annual harvested area. Annual harvested area estimates are developed from 1975 age distribution data (Figure 5). With an eye towards developing a lower-limit potential for expansion, three conservative assumptions were employed:

(1) Annual harvest is evenly distributed within the five year age groups specified in age distribution data.

(2) Area that is presently beyond harvest age will never be harvested.

(3) Softwood stand yields are held at averages for the early 1970s regardless of the stand age assumption.

This volume estimate (368.7 m^3/hectare) is consistent with the emphasis on gauging the effects of changes in harvestable area.[6] All other things being equal, failure to account for harvested timber maturity will produce underestimates for older stands and overestimates for younger stands. On balance, however, this is probably a conservative yield estimate since part-cut areas and less productive government land are included in the computation.

Roundwood projections based on this method are shown in Table 3. The level of projected output for the 1975 to 1980 period is indicated for four maturity assumptions between 35 and 50 years. Changes in output arise only because of increased harvest on non-national artificial forests. Production from national forests is held at 1975 values. Also, harvest from non-national forests is held at 1975 values which imply that 1975 actual output is equal to projected output for the 1975 to 1980 period. These estimates indicate that increasing softwood supplies are plausible. For 35 and 40-year rotations output doubles by the early 1990s. Under longer rotations (45 or 50 years), however, significant output expansions would not occur until the late 1990s.

The harvest age should depend on economic conditions, especially on the private forests (27). The expectation of rising timber prices would increase the gain from holding timber for future sale. This would tend to increase the harvest age, for example, to 45 or 50 years. On the other hand, the prospect of falling prices would make the postponement of sales less profitable. This would encourage shorter rotation periods, perhaps 35 to 40 years.

[6] The area included is clear-cut area on all natural and artificial forests, regardless of ownership. The historical averages from the 1972 to 1977 period were used for area and roundwood production.

B. HOUSING

Residential construction in Japan expanded dramatically in the 1960s and early 1970s in response to a housing shortage fueled by population growth, rural-to-urban migration and household undoubling. As of the mid-1970s, however, the number of available units has come into line with the number of households (18). Consequently, future investments in new housing would take the form of quality improvements and new households. For example, there is a high potential for replacing delapidated housing that was constructed in the 1950s. Also, the size of the typical dwelling is small by American standards so average floor space could continue to increase. Finally, historical trends away from more than one family in a dwelling could continue.

Ueda's recent report on Japan's housing requirements features projections of new housing investment based on demographic and economic factors (24). This study built on the premise that increases in new housing (S_t) consists of three separate components:

$S_t = h_t + \gamma_t + r_t$, where

h_t : increase in the number of households

γ_t : increase in the number of vacant units

r_t : increase in the number of removals

Increases in household formations were projected on the basis of demographic data and vacancy rates assumed a continuation of past trends. Increases in removals were considered responsive to per capita income (or GNP) and the interest rates charged on financing new housing. Thus, removal forecasts were based on assumptions for GNP growth and interest rates. Under a high growth assumption, annual GNP increases were between 6.5 and 7.5 percent. A low growth assumption featured GNP increases between 4.5 and 3.0 percent. Interest rates were held constant in both cases.

Although Ueda's study emphasized the number of available units, a "target level" of floor space from survey data was cited and it was assumed that this floor area would be realized by the end of the 1990s. This assumption amounts to a 20 percent increase in average floor space by 2000.

Table 4 contains Ueda's housing unit projections for high and low growth scenarios, assumptions about the increase in average floor space, and shows the conversion of these projections into the total floor area for new housing. The low growth housing unit forecast is combined with the assumption of a 20 percent increase in floor area by 1980. The high growth housing unit projection is combined with a more optimistic projection of average floor area (30 percent increase by 2000).

C. LOG TRADE

The effect of developments in Japan's log output and new housing construction can be estimated with the impact multipliers of Table 4. Under the assumption that no other changes occur, the relation among

Table 4. Housing starts and floor area projections by growth assumption through 1980.

	Low growth			High growth		
Year	Housing starts (mill units)	Floor area (20 percent) (m^2/house)	Total area mill m^2	Housing starts (mill units)	Floor area (30 percent) (m^2/house)	Total area mill m^2
1980	1.577	87.0	137.2	1.652	87.0	143.7
1981	1.584	87.85	139.2	1.676	88.6	148.5
1982	1.644	88.70	145.8	1.761	90.21	158.9
1983	1.638	89.55	146.7	1.758	91.82	161.4
1984	1.643	90.40	148.5	1.765	93.43	164.9
1985	1.620	91.25	147.8	1.757	95.03	166.9
1986	1.583	92.10	145.8	1.735	96.64	167.7
1987	1.626	92.95	151.1 (max)	1.795	98.24	176.3
1988	1.549	93.80	145.3	1.720	99.85	171.7
1989	1.570	94.65	148.6	1.761	101.45	178.7
1990	1.506	95.5	143.8	1.709	103.1	176.2
1991	1.551	96.35	149.4	1.768	104.6	184.9
1992	1.516	97.20	147.4	1.745	106.3	185.5
1993	1.470	98.05	144.1	1.712	107.9	184.7
1994	1.440	98.90	142.4	1.695	109.5	185.6
1995	1.413	99.75	140.9	1.681	111.1	186.6
1996	1.350	100.60	135.8	1.631	112.7	183.8
1997	1.335	101.45	135.4	1.640	114.3	187.5
1998	1.285	102.30	131.5 (min)	1.603	115.9	185.8
1999	1.318	103.15	135.9	1.650	117.5	193.8
2000	1.289	104.0	134.1	1.636	119.1	194.8

Table 5. Japan's housing construction, roundwood production, and U.S. log trade.

Under two scenarios

	Low income growth/high roundwood production			High income growth/low roundwood production		
	House construction[1] (3 percent income growth) mill m^2 floor area	Roundwood production[2] (35- year rotation) mill m^3	U.S. log exports to Japan[3] mill m^3	House construction[1] (6 percent income growth) mill m^2 floor area	Roundwood production[2] (50-year rotation) mill m^3	U.S. log exports to Japan[3] mill m^3
1976 Actual		20.9	10.4		20.9	10.4
1981-85	145.6	25.5	8.6	159.6	22.5	11.0
1986-90	146.9	51.8	0	174.1	25.3	9.7
1991-95	144.8	92.2	0	185.5	29.0	8.1
1996-2000	134.5	113.5	0	189.1	33.6	5.3

[1] Source: Table 4.
[2] Source: Table 3.
[3] Reductions in Japan's import demand come entirely at the expense of U.S. trade because of the residual supplier assumption. Thus, zero trade with the U.S. is consistent with several states of Japan's log trade. If the assumption that alternative exporting countries' foreign supplies are perfectly inelastic is abandoned, then expanded Japanese supply beyond zero-U.S. trade levels first mean a reduction in trade with Russia and New Zealand. Even more abundant supplies in Japan would suggest that Japan would take the role of an exporting country.

log trade (QILJUS), Japan's roundwood production (QRPJ), and housing starts is:

$$\Delta QILJ = -.6286\Delta QPRJ + .0492\Delta HSJR^{7}$$

Using 1976 data, this difference equation can be converted to a linear relation among these three variables:

$$QILJ = 17.91 - .6439QPRJ + .0492HSJR$$

Table 5 illustrates some extreme outcomes of Japan's domestic lumber market and the log trade for the next two decades.

Under one scenario income growth is brisk (6 percent) and relatively mature (50-year) timber is harvested. In this case, domestic softwood harvest would expand only slightly through the 1980s but in the 1990s output would exceed the 1975 level by at least 50 percent. New housing construction would expand gradually over the 20-year period, as strong replacement demand for housing and increases in floor area offset the declining number of household formations through the 1990s. Under this scenario trade would remain stable (near 10 mill m^3), throughout the 1980s but would drop gradually during the 1990s as softwood harvest increased. Log trade at the end of the 1990s would be about half the 1975 level (5.3 mill m^3).

In the second scenario, income growth is more moderate (3 percent) so replacement demand for housing is weaker and floor area expansions do not offset projected declines in household formation. Consequently new construction would expand through the 1980s, but decline during the 1990s. In this bleak scenario, weak lumber demand is coupled with the harvest of relatively young timber (35-year). In this case, domestic production more than doubles (51.8 mill m^3) by the mid-1980s and keeps expanding throughout the remainder of the 20th century. Log trade would decline slightly during the early 1980s and vanish during the remainder of the 20th century.

[7] The impact multiplier of Japan's sawlog production on U.S. log imports is –.7666. Given an 84 percent conversion of roundwood to sawlogs, the equivalent roundwood multiplier is –.6439.

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Appendix A

Table 1*

	Endogenous variables							
Year	QDSJ(g)	QPSJ(g)	QDLJ(g)	QILJ(g)	PJLUM(a,b)	PJLOG(m)	PUSLOG(k)	PUSLUM(k)
1960	21233.4	21233.40	–	–	15536.0	81.98	63.0	67.72
1961	22481.0	22481.00	–	–	20286.0	96.30	63.0	65.72
1962	22242.0	21870.00	29390.0	1687.0	20128.0	100.00	61.9	66.72
1963	24346.0	23724.00	31320.0	2636.0	20536.0	102.15	62.7	67.72
1964	25403.0	24837.0	34237.0	3298.0	20761.0	99.87	64.9	66.58
1965	26755.0	26279.0	34465.0	3509.0	20611.0	100.42	67.9	66.72
1966	28622.0	27993.0	36487.0	4504.0	21853.0	104.03	70.0	68.91
1967	31229.0	30139.0	39430.0	6767.0	24586.0	128.52	73.4	69.73
1968	32814.0	31467.0	41404.0	9175.0	25675.0	137.57	87.5	91.12
1969	33397.0	32450.0	39350.0	8540.0	26250.0	139.20	107.8	92.90
1970	33829.0	32750.0	41337.0	10238.0	25542.0	136.92	100.7	94.13
1971	32292.0	31381.0	37941.0	7718.0	24333.0	129.55	100.1	97.77
1972	33309.0	32344.0	42373.0	11187.0	33958.0	144.00	119.1	117.48
1973	33849.0	32513.0	43643.0	11810.0	48167.0	207.24	207.0	152.23
1974	30717.0	29515.00	37360.0	9815.0	46250.0	238.74	209.7	135.05
1975	28351.0	27362.0	35934.0	10383.0	44000.0	227.58	197.6	137.64
1976	30102.0	28649.0	37771.0	11097.0	47500.0	232.60	231.3	167.98

	Exogenous variables							
Year	QISJCAN(g)	QILJSOV(g)	QILJO(g)	WJ(h)	CAP	EX(h,j)	WPIUS(j)	DSTRIKE
1960	–	–	–	15.4	.648	359.60	94.9	0
1961	–	–	–	16.9	.686	361.80	94.5	0
1962	372.0	1184.0	552.0	19.8	.724	359.60	94.8	0
1963	622.0	1361.0	575.0	22.7	.763	362.40	94.5	0
1964	566.0	1753.0	624.0	64.9	.801	358.49	94.7	0
1965	476.0	2035.0	666.0	27.1	.839	361.49	96.6	0
1966	629.0	2558.0	900.0	30.4	.877	362.35	99.8	0
1967	1090.0	3971.0	1315.0	35.2	.915	362.15	100.0	0
1968	1347.0	4991.0	2129.0	41.1	.953	360.55	102.5	0
1969	947.0	5355.0	2282.0	48.0	.991	358.37	106.5	0
1970	1079.0	6167.0	2702.0	54.8	1.000	358.15	110.4	0
1971	911.0	6165.0	2738.0	63.2	1.000	348.03	114.0	1.000
1972	965.0	6801.0	2596.0	75.7	1.000	303.11	119.1	-1.000
1973	1336.0	7811.0	2603.0	98.5	1.000	271.22	134.7	0
1974	1202.0	7174.0	1938.0	118.8	1.000	291.51	160.1	0
1975	989.0	6895.0	1046.0	128.7	1.000	296.80	174.9	0

	Exogenous variables						
Year	HSJR(i)	HSJNR(i)	HSUS(l)	HSCAN	QPLJ(g)	QPLUS(g)	QPLCAN(g)
1960	28.972	32.489	1296.0	108.858	24576.0	131235.0	45369.0
1961	35.588	42.281	1365.0	125.577	26020.0	142280.0	51231.0
1962	35.757	40.888	1492.0	130.095	25967.0	142166.0	54599.0
1963	42.602	44.602	1642.0	148.624	26748.0	150804.0	57961.0
1964	46.930	58.800	1561.0	165.658	28562.0	153778.0	58741.0
1965	53.630	48.670	1510.0	166.565	28255.0	157318.0	59222.0
1966	57.810	51.927	1196.0	134.474	28525.0	155902.0	58919.0
1967	70.387	67.011	1322.0	164.123	27377.0	170345.0	63368.0
1968	83.605	76.865	1546.0	196.878	25109.0	158025.0	69746.0
1969	93.971	88.776	1500.0	210.415	23173.0	156468.0	71273.0
1970	104.746	100.288	1469.0	190.528	22230.0	172611.0	73517.0
1971	105.796	91.941	2084.0	233.653	21320.0	162839.0	76327.0
1972	134.707	109.132	2378.0	249.914	21789.0	163500.0	91865.0
1973	152.421	129.330	2058.0	268.529	21419.0	157034.0	80649.0
1974	114.123	84.430	1352.0	222.123	18433.0	152786.0	69322.0
1975	120.402	75.890	1171.0	231.456	17610.0		

*Sources are listed following the data table. The letter of the source is indicated immediately after each variable name in the table sub-heading.

Appendix A (Sources)

(a) *Monthly Report of the Lumber Market,* Japan Forestry Ministry, No. 337.

(b) *Monthly Report of the Lumber Market,* Japan Forestry Ministry, No. 295.

(c) *Japan Economic Journal,* International Weekly Edition.

(d) *Forest Product Statistics: Price Series 1950-1976,* United Nations Timber Bulletin for Europe, Vol. 30, Supplement 6.

(e) *White Paper on Japan's Forestry Industry: 1965.* Japan Lumber Journal.

(f) *Monthly Statistics of Agriculture, Forestry and Fisheries,* Ministry of Agriculture and Forestry. March, 1978.

(g) *Yearbook of Forest Products,* FAO/UN, various issues.

(h) *Japan Statistical Yearbook,* Bureau of Statistics, Office of the Prime Minister.

(i) *Statistics on Forest Products Concerned,* Forest Products Division, Forestry Agency. August, 1977.

(j) *International Financial Statistics,* Bureau of Statistics, International Monetary Fund. December, 1978.

(k) *Production, Prices, Employment and Trade in Northwest Forest Industries: Second Quarter 1977,* Pacific Northwest Forest and Range Experiment Station, USDA, Forest Service.

(l) *The Demand and Price Situation for Forest Products: 1976-77,* Forest Service, USDA, Miscellaneous Publication No. 1357.

(m) An index of wholesale log prices in Japan for pine and cedar was constructed. Data for cedar and pine log prices during the post-1970 period are available in (a) and (b). Documentation of data for earlier years and the method used in computing the price index can be obtained from the author.

Appendix B

The intention here is to illustrate the effects of a more restrictive quota on log and lumber prices. The effects of erecting a quota are thereby demonstrated as a corollary. First, we consider the "immediate impacts" outlined in the graphical exposition of the main body of the paper. Then the secondary adjustments that bring log and lumber markets back to equilibrium are discussed with reduced form equations.

Two sets of equations which describe the domestic softwood economies for Japan and North America form the building blocks for this exercise:

Japan

(1J) $QDSJ = \alpha_1^J - \beta_1^J PJLUM$

(2J) $QPSJ = \alpha_2^J + \beta_2^J PJLUM - \gamma_2^J PLOG$

(3J) $QDLJ = \alpha_3^J + \beta_3^J PJLUM - \gamma_3^J PLOG$

(4J) $QPLJ = \alpha_4^J + \gamma_4^J PLOG$

(5J) $QPSJ + QISJ^* = QDSJ$

(6J) $QPLJ + QILJ = QDLJ$

North America

(1A) $QDSA = \alpha_1^A - \beta_1^A PALUM$

(2A) $QPSA = \alpha_2^A + \beta_2^A PALUM - \gamma_2^A PLOG$

(3A) $QPLA = \alpha_3^A + \beta_3^A PALUM - \gamma_3^A PLOG$

(4A) $QPLA = \alpha_4^A + \gamma_4^A PLOG$

(5A) $QPSA = QDSA + QISJ^*$

(6A) $QPLA = QDLA + QILA$

where,

QDSJ: sawnwood domestic consumption, Japan

QDSA: sawnwood domestic consumption, North America

QPSJ: sawnwood production, Japan

QPSA: sawnwood production, North America

QDLJ: log domestic consumption, Japan

QDLA: log domestic consumption, North America

QPLJ: log domestic production, Japan

QPLA: log domestic production, North America

PJLUM: lumber price, Japan

PALUM: lumber price, North America

PLOG: log price in Japan and North America

QISJ*: sawnwood imports, Japan (exogenous)

The discussion of price behavior is cast in terms of equations which describe equilibrium in each of the three interrelated softwood markets. The first relationship states that Japan's lumber market is in equilibrium. From (1J), (2J) and (5J), it follows that:

$$\text{(A) PJLUM} = \frac{\alpha_1^J - \alpha_2^J}{\beta_1^J + \beta_2^J} + \frac{\gamma_2^J}{\beta_1^J + \beta_2^J}\text{PLOG} - \frac{1}{\beta_1^J + \beta_2^J}\text{QISJ*} .$$

Similarly, North America's lumber market is in equilibrium when

$$\text{(B) PALUM} = \frac{\alpha_1^A - \alpha_2^A}{\beta_1^A + \beta_2^A} + \frac{\gamma_2^A}{\beta_1^A + \beta_2^A}\text{PLOG} + \frac{1}{\beta_1^A + \beta_2^A}\text{QISJ*}$$

from (1A), (2A) and (5A). Log market equilibrium depends on conditions in Japan [equations (3J), (4J) and (6J)] and North America [equations (3A), (4A) and (6A)]. It follows that

$$\text{(C) PLOG} = \frac{(\alpha_3^J - \alpha_4^J) - (\alpha_4^A - \alpha_3^A)}{L} + \frac{\beta_3^J}{L}\text{PJLUM} + \frac{\beta_3^A}{L}\text{PALUM}$$

where $L = \gamma_3^A + \gamma_4^A + \gamma_3^J + \gamma_4^J$

INITIAL EFFECTS

First, consider the lumber market in isolation; From equation (A) above, it follows that

$$\Delta\text{PJLUM} = -\frac{1}{\beta_1^J + \beta_2^J} \cdot \Delta\text{QISJ*}$$

A more restrained quota or the imposition of a quota, say $\Delta\text{QISJ*} = -1$, raises Japan's lumber price by $\frac{1}{\beta_1^J + \beta_2^J}$. Similarly, the relation between the quota and North American lumber price is

$$\Delta\text{PALUM} = \frac{1}{\beta_1^A + \beta_1^A}\Delta\text{QISJ*}$$

from equation (B). These lumber price changes correspond to Figure 2.

In turn, the lumber price adjustments alter the log market equilibrium as in Figure 3. From equation (C),

$$\Delta\text{PLOG} = \frac{\beta_3^J}{L}\ \Delta\text{PJLUM} + \frac{\beta_3^A}{L}\Delta\text{PALUM}$$

The log price change resulting from the quota is obtained by substituting for the lumber price effect:

$$\Delta\text{PLOG} = \frac{[S^A - S^J]}{L}\ \Delta\text{QISJ},$$

where, $S^A = \beta_3^A/(\beta_1^A + \beta_2^A)$ and $S^J = \beta_3^J/(\beta_1^J + \beta_2^J)$. Thus, a more restrictive quota will increase log prices $(\frac{\Delta\text{PLOG}}{\Delta\text{QISJ}} < 0)$, provided that the shift in North American log demand, S^A, is small relative to the shift in Japanese log demand, S^J.

REDUCED FORM

A series of adjustments in log and lumber markets must occur before all three markets are in a consistent equilibrium. For example, the new log equilibrium adjusts lumber production plans in both countries, thereby setting off more adjustment in lumber price. In turn, a new log equilibrium is established. The equilibrium that is consistent with equilibrium in all three markets is given by the simultaneous solution of (A), (B), and (C). Converting to first differences and substituting (A) and (B) into (C) yields:

$$\Delta\text{PLOG} = \frac{\beta_3^J}{L}\left[\frac{\gamma_2^J}{\beta_1^J + \beta_2^J}\ \Delta\text{PLOG} - \frac{1}{\beta_1^J + \beta_2^J}\ \Delta\text{QISJ}\right] + \frac{\beta_3^A}{L}\left[\frac{\gamma_2^A}{\beta_1^A + \beta_2^A}\ \Delta\text{PLOG} + \frac{1}{\beta_1^A + \beta_2^A}\ \Delta\text{QISJ*}\right]$$

Rearranging gives:

$$\Delta\text{PLOG} = \frac{S^A - S^J}{L - S^J\gamma_2^J - S^A\gamma_2^A}\Delta\text{QISJ}$$

The denominator, $L - S^J\gamma_2^J - S^A\gamma_2^A$, represents the sum of slopes for foreign log supply and demand schedules. L gives the direct effects – the coefficients for log supply and demand schedules. The terms, $S^A\gamma_2^A$ and $S^J\gamma_2^J$, give log market adjustment to log price that result from adjustment in the lumber market. It is reasonable to assume that the foreign log supply is upwards sloping and foreign log demand curves are downward sloping, *i.e.*, that $L - S^A\gamma_2^A - S^J\gamma_2^J > 0$. Thus, log prices rise with the quota $(\frac{\Delta\text{PLOG}}{\Delta\text{QISJ}} < 0)$ when $S^J > S^A$, *i.e.*, when the shift in Japan's log demand exceeds the shift in American log demand.

Lumber price changes are obtained by substituting the expression for the log price change into (A)

$$\Delta\text{PJLUM} = \left[\frac{\gamma_2^J}{\beta_1^J + \beta_2^J} \cdot \frac{S^A - S^J}{L - S^J\gamma_2^J - S^A\gamma_2^A} - \frac{1}{\beta_1^J + \beta_2^J}\right]\Delta\text{QISJ*}$$

or

$$\Delta\text{PJLUM} = \left[\frac{\gamma_2^J(S^A - S^J)}{L - S^J\gamma_2^J - S^A\gamma_2^A} - 1\right]\ \frac{\Delta\text{QISJ*}}{\beta_2^J + \beta_2^J}$$

As before, the term $\frac{1}{\beta_1^J + \beta_2^J}$ represents the lumber price change that follows from a change in the quantity of lumber. The bracketed term shows that a more restrictive quota will increase Japanese lumber price, $(\frac{\Delta\text{PJLUM}}{\Delta\text{QISJ}}) < 0$, provided that the indirect effects of the quota on domestic production, $\frac{\gamma_2^J(S^A - S^J)}{L - S^J\gamma_2^J - S^A\gamma_2^A}$, do not offset the direct effect of the quota in reducing domestic lumber supply (– 1). When $S^J > S^A$, the lumber price will always increase, and when $S^A > S^J$, the price will still rise, provided that the difference, $S^A - S^J$, is small.