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D. M. Adams, B. A. McCarl, and L. Homayounfarrokh

CENTER FOR INTERNATIONAL TRADE IN FOREST PRODUCTS
UNIVERSITY OF WASHINGTON
COLLEGE OF FOREST RESOURCES AR-10
SEATTLE WASHINGTON 98195

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Darius M. Adams

Bruce A. McCarl

and

Lalehrokh Homayounfarrokh

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Darius M. Adams is Professor, Center for International Trade in Forest Products, College of Forest Resources, University of Washington, Seattle, WA. Bruce A. McCarl is Professor, Department of Agricultural Economics, Texas A & M University, College Station, TX. Lalehrokh Homayounfarrokh is a graduate student, Department of Agricultural & Resource Economics, Oregon State University, Corvallis, OR.

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ABSTRACT

The paper employs graphical analysis, simple statics and an econometric model to examine the impacts of exchange rate on consumption, production, prices and bilateral trade flows in the Canadian-U.S. lumber market. Based on annual data for the 1950-1983 period, the econometric model is comprised of a U.S. demand relation and supply, capacity, and stumpage price relations for three U.S. regions and Canada. Analysis with the model indicates short-term elasticities with respect to exchange rate (expressed as $C/$US) of less than .1 for U.S. consumption, roughly -.3 for U.S. delivered price and .5 for import volume. The elasticity of Canadian market share was found to be in the range of .4 to .6. The greatest Canadian market share expansion (from roughly 20 to 28 percent) and rise in U.S. dollar strength occurred during the years 1975-1979. An hypothetical simulation of this period, under the assumption of no increase in the nominal exchange rate, yielded a reduction in Canada's 1979 share to 25%, roughly a 40 percent reduction in share growth rate. Both elasticity and simulation results indicate that exchange rate has been an important, but by no means the sole, factor in recent expansion of Canada's share in U.S. lumber markets.

THE ROLE OF EXCHANGE RATES IN CANADIAN-U.S. LUMBER TRADE

In the on-going debate over the causes of rising U.S. softwood lumber imports from Canada, relative production costs (primarily stumpage charges) and the Canadian-U.S. exchange rate have received the greatest attention. The U.S. International Trade Commission (1982, 1985) and industry groups have provided extensive comparisons of costs between U.S. and Canadian producers. Examination of the role of exchange rates, however, has been somewhat less thorough. Discussion to date has focused on the apparent pricing advantage afforded Canadian producers by a strengthening U.S. dollar but has not considered the influence of other market aspects of supply and demand (USITC, 1985; McCarl and Haynes, 1985).

This paper presents an expanded analysis of the role of exchange rate in Canadian-U.S. lumber trade, employing an econometric model of the North American lumber market. The objectives are to explicate the conditions which govern the influence of exchange rate and to provide estimates of exchange rate impacts on prices, consumption production, and trade. The following sections summarize recent exchange rate history and exchange rate-cost interaction, develop preliminary estimates of rate impacts from a simple theoretical model and a review of past studies, describe the econometric model and its estimation, and present results of simulation experiments designed to estimate the *ceteris paribus* impacts of shifts in the exchange rate.

Exchange Rates in a Market Context

As indicated in Figure 1, the nominal Canadian-U.S. exchange rate began a sharp rise in 1977, after more than 25 years of relatively limited fluctuation. Between 1977 and second quarter 1985 the rate rose by nearly

29 percent. _If all else were held constant_, such an increase could represent a considerable improvement in the competitive advantage of Canadian lumber producers in U.S. markets. Each 1 percent rise in the exchange rate corresponds to a 1 percent reduction in the delivered U.S. dollar price of Canadian products. Such an advantage might be realized as increased unit profits or exploited, through price competition, to expand Canadian producers' share of U.S. markets. Indeed, over the period from 1976 to early 1985, Canada's share of U.S. softwood lumber markets rose by roughly 10 percent in close parallel with rising exchange rates (see Figure 1).

The difficulty with this simple analysis and its conclusions, of course, is that all other forces influencing lumber production and pricing decisions have not remained constant. Growth in the strength of the U.S. dollar relative to the Canadian dollar over the past decade was accompanied by sharply rising general price and cost levels in both economies. Inflation in general Canadian producer prices has been greater than that in the U.S. since 1975. If exchange rate movements are driven solely by inflation (cost) differentials between countries, as suggested by the traditional "purchasing power parity" theory (see, for example, Caves and Jones, 1981), no trading advantage would arise from an exchange rate movement. The percentage rise or fall in the exchange rate would match the inflation (cost) differential between countries and trading partners would remain in the same relative positions.

For a particular commodity, such as softwood lumber, the effects of an exchange rate movement depend on shifts in the exchange rate and the specific costs of lumber production. In a competitive lumber market, an exchange rate movement between period t-1 and t would be favorable to Canadian producers if the growth in Canadian producer costs relative to the growth in U.S. costs over the same time interval were less than the change in the exchange rate. Specifically, Canadian producer cost in U.S. dollars can be represented as:

$$C_{u,t} = C_t/X_t$$

where $C_{u,t}$ is Canadian producer cost in \$ U.S. (\$US),

C_t is Canadian producer cost in \$ Canadian (\$C), and

X_t is the exchange rate (\$C/\$US), all at time t.

If U_t is the cost of U.S. producers, then the condition

$$\frac{C_{u,t}/U_t}{C_{u,t-1}/U_{t-1}} < 1 \tag{1}$$

would imply a favorable movement in Canadian costs relative to U.S. producer costs and hence a potential basis for enhanced price competition in the delivery market (the U.S.). Rearranging (1), using the above definitions, yields the basis for the original assertion:

$$\frac{C_t/C_{t-1}}{U_t/U_{t-1}} < \frac{X_t}{X_{t-1}} \tag{2}$$

the change in exchange rate must exceed any change in relative costs to provide a potential trading advantage to Canadian producers. Condition (2) can be rewritten as:

$$\frac{[C_t/C_{t-1}]/[U_t/U_{t-1}]}{[X_t/X_{t-1}]} < 1 \tag{3}$$

Figure 2a shows the composite condition (3) calculated for Canadian softwood lumber production costs (C) and costs in the western coastal region (Douglas-fir and California regions) of the U.S. (U). Superimposed on the chart is a plot of the period to period movement in the Canadian share of U.S. apparent softwood lumber consumption calculated as:

$$S_t/S_{t-1} \tag{4}$$

where S_t is Canadian market share in period t. The considerations above suggest that Canadian market share should rise (the ratio in (4) should move above 1) when condition (3) is satisfied and remain stable or fall when (3) is not satisfied. The data in Figure 2a are generally supportive of this conjecture, particularly in the period after 1971.

Figure 2b displays the left and right hand sides of equivalent condition (2), illustrating the behavior of the relative cost and exchange rate components. Also shown is the period to period movement in relative U.S./Canadian all commodity producer price indices. Three points should be noted in this figure. First, as suggested by the PPP theory, exchange rate movements follow those in relative price levels between the two countries. Second, it appears that historically costs have been the most volatile element of condition (2) with wide year to year swings. Third, and most significantly, costs and exchange rate have generally, though not uniformly, moved in a reinforcing fashion. That is, relative costs of softwood lumber production have moved in cycles counter to those in both exchange rate and relative prices in general. This behavior would have acted to augment the competitive effects of exchange rate movements.

The foregoing results suggest that both cost and exchange rate shifts have played important roles in determining relative trade advantage in the North American softwood lumber market over time. The methods employed to this point, however, provide only a composite view of cost and exchange rate acting in concert. The task of the remaining sections is to identify the *ceteris paribus* impacts of a movement in exchange rate alone.

Previous Studies

Several previous studies of the U.S. softwood lumber market explicitly consider Canadian-U.S. trade. Only three report sufficient detail, however, to allow identification of the impacts of exchange rate, and the results of these are quite diverse. Adams and Blackwell (1973) and Buongiorno, Chou and Stone (1979) estimate import demand equations for all Canadian softwood lumber in U.S. markets, employing exchange rate to convert Canadian prices to U.S. dollar equivalents. Elasticities of import volume with respect to the exchange rate calculated from Adams and Blackwell are .124 for a single year and .248 for the full two year distributed lag included in their model. Similar elasticities from the preferred equation estimated by Buongiorno, Chou and Stone are .35 for a single month and .45 for the full long-term effect. Robinson (1974) examined the U.S. import demand for Douglas-fir species lumber only, incorporating exchange rate as a separate shift term in his demand equation. Robinson found the elasticity of import volume with respect to exchange rate to be 1.15, while the elasticity of total U.S. demand volume with respect to exchange rate was estimated at .71.

Simple Statics

To provide a further basis for initial expectations of the impacts of exchange rate shifts on market prices and volumes, we consider some simple statics results from a two-country trade model. The model consists of Canadian net export supply, U.S. demand, U.S. net domestic supply (adjusted for exports), and appropriate identities as follows:

$$S^c = S^c(P^c) \qquad \text{Canadian net export supply} \qquad (5)$$

$$S^u = S^u(P^u) \qquad \text{U.S. net domestic supply} \qquad (6)$$

$$D^u = D^u(P^u) \qquad \text{U.S. demand} \qquad (7)$$

$$P^c = P^u X \qquad \text{Price equilibrium} \tag{8}$$

$$D^u = S^c + S^u \qquad \text{Market clearing} \tag{9}$$

where P^c is price in Canada ($C),

P^u is price in U.S. ($US), and

X is the exchange rate ($C/$US).

Possible feedback effects of changes in production capacity and factor prices resulting from changes in equilibrium prices and volumes are considered at the end of this section.

Substituting (5)-(8) in (9) we obtain:

$$D^u(P^u) = S^u(P^u) + S^c(X\ P^u) \tag{10}$$

Taking the total derivative of (10) and manipulating terms it can be shown that:

$$\frac{dP^u}{dX}\ \frac{X}{P^u} = e_{P,x} = \frac{e_{sc}\ s^c}{e_{Du} - e_{su}\ s^u - e_{sc}\ s^c} \tag{11}$$

The elasticity of equilibrium U.S. market price with respect to exchange rate ($e_{p,x}$) depends on the elasticities of U.S. and Canadian supply (e_{su} and e_{sc}), the elasticity of U.S. demand (e_{Du}), and the U.S. and Canadian shares of the U.S. market ($s^u = S^u/D^u$ and $s^c = S^c/D^u$). Since both supply elasticities and market shares are positive and the demand elasticity negative in the normal case, $e_{p,x} < 0$. Further, so long as U.S. demand elasticity is nonpositive and U.S. supply elasticity is non-negative, the absolute value of $e_{p,x}$ will be less than 1. Equation (11) also confirms the usual results of the classical "back-to-back" diagram analysis, that more elastic U.S. demand, U.S. supply and/or Canadian supply reduce the price effect of a shift in exchange rate.

To provide a somewhat more concrete illustration of the above results, consider the following values for the several elements in (11): $e_{Du} = -.2$,

$e_{su} = .3$, $e_{sc} = .7$, $s^c = .3$, and $s^u = .7$. The elasticity values are representative of results obtained by Adams and Haynes (1980), Haynes and Adams (1985) and similar studies. The market shares are approximately those of the early 1980s. Substituting these values in equation (11), the elasticity of equilibrium price with respect to exchange rate would be estimated at approximately -.30.

The effects of exchange rate on total U.S. market quantity are found by taking the total derivative of the U.S. demand equation (7) and substituting the above results for price, yielding:

$$\frac{dD^u}{dX} \frac{X}{D^u} = e_{D,x} = e_{Du}\, e_{p,x} \qquad (12)$$

Since the elasticity of demand is negative in the normal case and $e_{p,x}$ was also shown to be negative, the elasticity of equilibrium quantity with respect to exchange rate $e_{D,x} > 0$. From (11) and (12) it follows that increasing demand or supply elasticities will increase the quantity impact of the exchange rate. Based on the illustrative elasticity values given above, equation (12) provides an estimate of quantity elasticity with respect to exchange rate of .06.

The effects of exchange rate on the volume of Canadian imports is found by taking the total derivative of the Canadian export supply relation (5) and substituting results from equation (11), yielding an elasticity expression:

$$\frac{dS^c}{dX} \frac{X}{S^c} = e_{sc,x} = e_{sc}\,(1 + e_{p,x}) \qquad (13)$$

Since $e_{sc} > 0$ in the normal case and $1 > | e_{p,x} | > 0$, the elasticity of import quantity with respect to exchange rate will also be positive. An increase in the Canadian supply elasticity, or any shift which reduces the price effect of the exchange rate (such as increases in U.S. demand or supply elasticity), will increase the import quantity effect. Substituting the illustrative elasticity values in equation (13), we obtain an estimate of the elasticity of imports with respect to exchange rate of .49. This value is somewhat higher than the previously noted results from Adams and Blackwell (1973) and Buongiorno, Chou and STone (1979) and lower than that found by Robinson (1974).

To this point the effects of potential feedback from factor prices (such as stumpage price) and capacity/investment behavior in the simple model have been ignored. In qualitative terms if changes in a factor price are positively related to changes in the product price, the supply function(s) will be found, after due allowance for this feedback, to be less elastic than before. From the results above, this should lead to larger price effects and smaller volume effects from a shift in exchange rate. If a capacity change is reflected in a horizontal shift in the supply function (to the right in price/quantity space if capacity expands) and if capacity change is positively related _ceteris paribus_ to product price, the effect is to increase the apparent supply elasticity. This should act to lower the price effect and raise the volume effect of a shift in exchange rate.

A Model of North American Lumber Markets

The model developed to examine the effects of exchange rate is based on the simple structure of equations (5)-(9) but includes a more elaborate representation of producing regions in the U.S., explicitly recognizes the role of transportation costs in establishing delivery price, and includes relations to approximate the feedback of stumpage prices and capacity decisions on supply behavior. Four producing regions are identified in the U.S.: "Coast" encompassing the Douglas-fir and California regions; "Interior" including the Ponderosa pine region of eastern Oregon and Washington and the Rocky Mountain states; "South" comprising the southern pine producing states; and the "North" including the northcentral and northeastern states. Production in the North was taken as exogenous.

Equations were estimated using two-stage least squares with exceptions as noted below. All relations except the capacity adjustment equations were estimated with a data sample spanning the years 1950 through 1983. Capacity adjustment equations were estimated, and the model was simulated, over the data sample from 1964 through 1983. Definitions, units and sources of data for variables used in the following discussion are given in Table 1. Note that all prices and costs are expressed in units of dollars per thousand board feet, lumber tally (MBF, LT), in currency units appropriate for the country in question, and deflated by the all commodity producer price index (1967 = 1.0) for the U.S. or Canada as appropriate.

U.S. Demand for Softwood Lumber

The U.S. demand relation was expressed in use factor form (Cardellichio and Veltkamp, 1981; Kallio, Brannlund, and Uutela, 1984), were end use activity (I) is represented by a composite index of construction and manufacturing activity. Substitute prices (PS) are represented by a composite index of softwood plywood, building block and brick prices. Graduate adjustment of consumption to changes in relative prices is represented by inclusion of a moving average of relative prices and the once lagged value of the dependent variable. The resulting distributed lag structure has a modal shape, with gradually rising weights for lags to the end of the moving average (year t-2) and exponentially declining weights thereafter. Estimation results using two stage least squares were:

$$\ln\left(\frac{TUSC}{I}\right) = \underset{(.424)}{1.29982} - \underset{(.209)}{.357143}\left[\left(\frac{1}{3}\right)\sum_{i=0}^{2}\frac{USDP_{t-i}}{PS_{t-i}}\right]$$

$$+ \underset{(.0548)}{.842544}\ln\left(\frac{TUSC_{t-1}}{I_{t-1}}\right) \qquad (14)$$

$$\bar{R}^2 = .91,\ DW = 1.42,\ SMPL = \text{'52-'83},$$

where $\bar{R}^2$ is adjusted for degrees of freedom, DW is the Durbin-Watson statistic, SMPL is the effective estimation sample, and the figures in parentheses below the coefficients are estimated standard errors. The elasticity of demand averages -.126 over the sample period. The median lag of the composite distributed lag structure for relative prices is between 4 and 5 years. As a comparison, Spelter (1985) found that under the market conditions of the early 1970s softwood lumber demand elasticity might be expected to increase to three times the short-term level after a five year period. His estimates rise from an elasticity of -.13 for a single year to -.39 after a five year adjustment period, with little change in subsequent periods. In the present model, demand elasticity rises from an estimate of -.11 in 1983 to -.40 after five years and ultimately to -.70 after full operation of the adjustment process.

Lumber Supply Relations

Lumber supply relations were estimated in the general form employed by Haynes and Adams (1985), with output a linear function of operating margin--price (P) less nonwood costs (PC) less stumpage costs (ST) plus residue revenues (RES)--and capacity (K). The final supply relation in the form for estimation is:

$$S_{r,t} = A_{o,r} + A_{1,r} [P_{r,t} - PC_{r,t} - ST_{r,t} + RES_{r,t}] + A_{2,r} K_{r,t} \quad (15)$$

where the subscript r is a regional designation. For Canada, wood cost is included in the PC term. Estimation results are shown in the following tabulation. The estimation sample is 1950-1983 in all cases. The estimation method (METH) is either two-stage least squares (TSLS) or TSLS adjusted for serial correlation (ITSLS). Note that Canadian prices and costs are measured in Canadian currency deflated by the Canadian producer price index. Estimates of the elasticity of supply with respect to price computed at sample period means for these relations are: Coast .239, Interior .460, South .510, and Canada .483. Deducting exogenous volumes

	------Coeffiсent Estimates------					
Region	Intercept	Margin	Capacity	$\bar{R}^2$	DW	METH
Coast	-10439.5 (2789.5)	32.8283 (14.69)	1.56165 (.1873)	.79	1.73	TSLS
Interior	-280.715 (449.72)	25.6839 (6.205)	.895022 (.0660)	.88	1.75	TSLS
South	464.103 (797.20)	33.6438 (10.09)	.733060 (.0920)	.86	1.78	ITSLS
Canada	-825.086 (678.01)	63.2842 (21.80)	.919711 (.0459)	.96	1.67	ITSLS

for Canadian consumption and off-shore shipments, the elasticity of Canadian export supply to the U.S. is estimated at .917.

Capacity Adjustment Relations

Decisions to expand or contract lumber production capacity were hypothesized to depend on changes in operating margin as:

$$K_{r,t} - K_{r,t-1} = b_{o,r} + b_{1,r} [PI_{r,t} - PI_{r,t-1}] \quad (16)$$

where $PI_{r,t}$ is the operating margin in region r in period t. It is expected that $b_{1,r}$ will be positive. This form is similar to capacity change relations used in Adams and Haynes (1980) and Haynes and Adams (1985) except that it excludes the fixed margin "target" incorporated in these earlier studies.

Capacity change is typically one of the most difficult aspects of market behavior to explain. In the present case this was seen in the inability of the simple model of equation (16) to track the reversal in capacity trends in the Interior and Southern regions in the mid 1960s and the large capacity increments in U.S. regions in the early 1980s. To accommodate these difficulties, the estimation sample was restricted to the 1964-1983 period and a dummy variable was included for the year 1983.

Estimation results are shown in the following tabulation. Ordinary least sqaures (OLS) results were used for the South and Canada, since TSLS gave implausible signs for the margin change terms.

	--------Coefficent	Estimates---------				
Region	Intercept	Margin Change	'83 Dummy	$\bar{R}^2$	DW	METH
Coast	-153.4339 (42.66)	13.36159 (4.15)	1.726.8 (192.3)	.84	1.06	TSLS
Interior	-38.3123 (38.23)	5.21428 (3.21)	965.7 (176.9)	.67	1.37	TSLS
South	202.8275 (46.04)	10.80006 (5.94)	763.7 (206.7)	.46	.68	OLS
Canada	558.6792 (83.96)	30.01842 (7.76)		.42	1.93	OLS

Stumpage Price Feedback

To account for the clear linkage between stumpage prices in U.S. regions and prices in the lumber market, and yet avoid the elaborate structural system employed by Adams and Haynes (1980) to explain stumpage price determination, we employ "price transmission" equations of the sort used by Adams and Blackwell (1973) and described in detail by Haynes (1977). These relations have the form:

$$ST_{r,t} - ST_{r,t-1} = c_{o,r} + c_{1,r} [P_{r,t} - P_{r,t-1}] \qquad (17)$$

Use of the first difference form avoids problems of multicollinearity and serial correlation but is employed here primarily on the grounds that stumpage markets are "efficient" (see, for example, Fama, 1970). That is, any current period changes in lumber markets or other influences are immediately reflected in current period stumpage price movements rather than in some graduate form as might be represented, for example, by a distributed lag process.

Stumpage price relations were estimated using data from the period 1951 through 1983. Results are shown in the following tabulation.

	-----Coefficent Estimates-------				
Region	Intercept	Lumber Margin Change	$\bar{R}^2$	DW	METH
Coast	.38105 (.544)	.212718 (.0486)	.36	2.11	TSLS
Interior	.07717 (.365)	.237946 (.0322)	.63	2.08	TSLS
South	.16716 (.873)	.442728 (.0886)	.43	1.78	TSLS

Identities

Volume balance in the North American lumber market is ensured by the identity:

$$TUSC + \overline{TCC} = S_{co} + S_I + S_s + S_{CA} + \overline{S}_N + \overline{USIO} + \overline{TUSE} + \overline{CEO} \qquad (18)$$

where overbarred variables are taken as exogenous and time subscripts have been omitted (see Table 1 for variable definitions).

Pricing identities link average delivered demand price (USDP) with prices at the mill level in the producing regions. For the three U.S. regions these relations have the form:

$$P_{r,t} = USDP_t - ATC_{r,t} \qquad (19)$$

For Canada the relation recognizes the payment of transport costs in two different currencies and exchange rate conversion:

$$P_{CA,t} \frac{1}{X_t} = USDP_t - ATC^{US}_{CA,t} - ATC^{CA}_{CA,t} \left[\frac{1}{X_t}\right] \qquad (20)$$

Historical Simulation Results

The explanatory power of the full model was examined by means of a simulation over the 1964-1983 period. The simulation error measures in Table 2 indicate that capacity remains one of the weaker elements of the model. Errors are generally lower for the more aggregative measures, e.g., total U.S. consumption and average demand price, and highest for stumpage prices and capacity. In qualitative terms, the model tends to overestimate capacity additions in the South, while overstating capacity reductions in the two western U.S. regions. Difficulties with stumpage prices were generally confined to the portion of the sample period prior to 1974, the model tending to understate price levels. Amplitude errors were much less pronounced in the 1975-1983 period.

Exchange Rate Analysis

Two sets of simulations were conducted to examine the impacts of exchange rate on market prices, volumes and Canada's share in total U.S. consumption. Short-term, or one period impacts, were estimated by simulating a single historical year using the actual exchange rate and the actual rate plus one percent. With all other exogenous variables held constant, the percentage changes between values of variables in the first and second simulations give estimates of their elasticity with respect to exchange rate. Long-term, or multi-period, elasticities were measured in a similar fashion, with all exogenous variables held constant except exchange rate and results measured after a twenty year simulation span.

As in the measurement of elasticity for any empirically estimated function and data base, results may vary depending on the specific values of the endogenous and exogenous variables at the measurement point. To illustrate the array of variation possible, three years were chosen for the present analysis: 1975 (a recessionary year with low output and prices), 1979 (a boom year with high output and prices) and 1983 (representative of recent conditions with high output and low prices). Because all prices and costs are deflated in the present model, the exchange rate employed in the model is the "real" rate (see Table 1 for definition). For the given relative prices of the base years, however, the results can be interpreted as elasticities with respect to both the real and nominal exchange rate.

Results of the simulations are shown in Table 3. All of the tabulated values are the percentage change in the variable indicated resulting from a one percent increase in the exchange rate. Since long-term results exhibited little variation among measurement points, only the values for 1983 are shown in the table. Prices of lumber and stumpage have the highest short-term elasticities with respect to exchange rate. Stumpage prices for the U.S. regions are somewhat more responsive than lumber prices, as might be expected given their highly volatile historical behavior. The exchange rate shift has a large impact on lumber prices in Canada. Both because of this large price change and because Canadian supply is quite sensitive to price (both in total and for export), the exchange rate responses of Canadian total and export supplies are two to three times larger than those for U.S. regions. The large Canadian price response is also reflected in the larger shift in Canadian lumber capacity. Given the relatively modest increase in total U.S. consumption, the elasticity of Canadian share of U.S. consumption is only slightly lower than that for Canadian export supply.

Comparing short-term results for the three alternative base years, variation in elasticity estimates is limited (less than 0.10 in absolute value) with the exception of Canadian lumber price, lumber supply, export and market share measures and U.S. stumpage prices. For these variables, the measurement point has some influence on the estimated elasticity. Variation in the Canadian elasticities can be linked to changes in the own price elasticity of Canadian supply in the three measurement years. In the model solutions, the elasticity of Canadian supply with respect to its own price differs significantly among the three years, with 1983 having the lowest, 1975 intermediate and 1979 the highest elasticity, respectively. Since an exchange rate shift can be likened to a price movement in Canada, the exchange rate elasticities of Canadian total and export supply and

Canadian market share vary in this same pattern. Canadian price being dependent in part on Canadian supply, its exchange rate elasticities vary in the opposite direction.

Variation in the elasticities of U.S. stumpage prices with respect to exchange rate derives from differences in the historical response of stumpage prices to changes in lumber prices. From equations (17), the elasticity of stumpage price with respect to exchange rate is approximately equal to the product of the elasticities of stumpage price with respect to lumber price and of lumber prices with respect to exchange rate. Results in Table 3 suggest that the latter elasticity has not varied significantly over the three measurement years. Historical data indicate, however, that stumpage prices are less sensitive to lumber prices in cyclical peaks (such as 1979) than during periods of lower lumber prices (such as 1975 and 1983). This behavior is embodied in the stumpage price relations (17) and leads to lower elasticities of stumpage price with respect to exchange rate in the high price year of 1979 than in the lower price years of 1975 and 1983.

Long-term results in Table 3 show a markedly different pattern across the several endogenous variables, as a result of model dynamics. As the long-term simulation proceeds, price reductions in the U.S. are gradually translated into rightward shifts in the demand function (due to the demand price adjustment in equation (14)) and reductions in stumpage prices (due to equation (17)). These changes act as buffers in the system. As a consequence, long-term impacts are largely concentrated in U.S. consumption and Canadian price and volume variables with impacts on U.S. producers reduced relative to the short-term results. The extent of the long-term demand elasticity adjustment and the sensitivity of stumpage prices to product price movements are directly related to the size of the long-term impacts of exchange rate shifts on Canadian price and output and indirectly related to those on U.S. regions.

As a second means of illustrating the impacts of varying exchange rates, we examine the development of the North American lumber market over the period from 1975 through 1979.[1/] This was the period of most rapid increase in the strength of the U.S. relative to the Canadian dollar, the exchange rate rising from 1.017 $C/$US in 1975 to 1.171 $C/$US in 1979. At the same time, Canada's share of U.S. softwood lumber consumption rose from 20.0% to 27.5%. From the chart in Figure 2b, it can be seen that (with the exception of 1979) this was also a period when Canadian lumber production cost growth was lower than that in the U.S. Coast region. The analysis attempts to estimate the extent to which rising exchange rate contributed to the growth in Canadian market share over this period.

An historical simulation was developed in which the exchange rate was held constant at its 1975 level over the ensuing years through 1979. Comparison of these results with a simulation in which the exchange rate followed this actual historical path provides estimates of exchange rate impacts. In conducting this experiment, it is assumed that all other exogenous variables in the model follow their historical time paths. Thus, the policies employed to affect a constant exchange rate are presumed to have no influence on the levels of these variables.

Results for key endogenous variables are shown in Table 4, both as percentage changes and absolute deviations from the base simulation values in 1979. The general pattern of results is similar to that for the short-term elasticities in Table 3. U.S. prices and Canadian supply volumes show the greatest variation. Canadian market share by 1979 is lower than the base value but has continued to expand from the 1975 level. Buffered by demand shifts and rising stumpage prices, increases in producer margins in U.S. regions are modest. As a result, U.S. production expansion is modest and the bulk of the adjustment is realized as reduced imports, Canadian output and Canadian market share.

Discussion and Conclusions

In terms of changes in relative costs and exchange rates as illustrated in Figure 2b, the experiment in which the exchange rate was held constant over the 1975-1979 period is equivalent to holding the exchange rate growth line at one. Under the conditions of this experiment it was found that an exchange rate reduction in excess of 15 percent by 1979 reduced Canada's market share in that year from 27.5 percent to 24.8 percent, roughly a 40 percent reduction in market share growth. This is not an insignificant effect, but the upward trend in Canada's share--from 20.0 percent in 1975--was not eliminated by stable exchange rates along.

The short-term elasticity results in Table 3 provide a means of illustrating the extent of exchange rate impacts in a different way. Suppose, for example, one wishes to estimate the exchange rate reduction between the years 1982 and 1983 that would have been needed to stabilize Canada's market share at the 1982 level. Over the 1982-1983 period, Canada's share rose from 29 percent to roughly 30 percent. This represents a percentage increase of market share in excess of 3 percent (1.0/29.0). The 1983 market share elasticity in Table 3 indicates that a share reduction of this magnitude would require about a 7 percent decline in the exchange rate in 1983, assuming all else remains constant. Such a decline would be roughly equivalent to returning the rate to its 1978 level.

Table 3 elasticities can also be used to estimate the impacts of this hypothetical rate reduction on U.S. consumers and producers. A 7 percent rate reduction under 1983 conditions would lead to an increase in aggregate U.S. softwood lumber production in excess of 0.7 percent, with the largest absolute and percentage gains in the Coastal and Interior regions. U.S. production expansion would be about one third less than the decline in imports from Canada, however, owing to the decline in volume demanded and the rise in domestic stumpage costs. Thus, in this single period example, just as in the longer 1975-1979 simulation, market contraction and higher costs restrict the potential benefit of an exchange rate decline to domestic producers.

In summary, the results of the simulation experiments are supportive of the general conclusions tentatively drawn from Figures 2a and 2b at the beginning of this paper. Increases in the Canadian-U.S. exchange rate have played a definite role in the expansion of Canadian share of U.S. markets over the past decade but appear to account for only part of the rising market share trend. Clearly other factors, including relative stumpage and non-wood production costs between the two countries, must be explored to explain the residual market share growth.

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Table 1. List of variable definitions and data sources.

Variable Name	Definition and (Source)[a]
$ATC^{CA}_{CA,t}$	Average transport costs from Canada to U.S.--the part paid in Canadian dollars. (U.S. demand price less Canadian mill price partitioned using data from industry sources.)
$ATC^{US}_{CA,t}$	Average transport costs from Canada to U.S.--the part paid in US dollars. (See source note above.)
$ATC_{r,t}$	Average transport cost from U.S. region r. (U.S. demand price less regional mill price.)[b]
CEO	Canadian softwood lumber exports to countries other than the US (Statistics Canada).
I	Index of activity in softwood lumber consuming end-uses. (Formed from indexes of housing starts, nonresidential construction and manufacturing activity, weighted by the shares of housing, non-residential construction and all other uses in softwood lumber consumption, 1967 = 1.0. Activity measures and weights from U.S. Forest Service.)
$KL_{r,t}$	Lumber production capacity in region r, period t (Authors' estimates).

Table 1. (Continued)

Variable Name	Definition and (Source)
$MC_{r,t}$	Average variable costs of lumber manufacture--stumpage excluded in U.S. but included in Canada. (Canadian costs from Statistics Canada, U.S. costs from U.S. Forest Service and authors' estimates.)
$PLUM_{r,t}$	Average wholesale (mill level) price of lumber in supply region r, year t. (Derived from data of Western Wood Products Association, Random Lengths, Inc., and U.S. Dept. of Commerce.)
PS	Index of the price of substitutes. (Weighted index of prices of softwood plywood, building blocks and bricks. Prices from American Plywood Association and U.S. bureau of Labor Statistics, weights authors' estimates.)
$RES_{r,t}$	Average residue revenues. (U.S. Forest Service and Statistics Canada.
$S_{N,t}$	Softwood lumber production in the Northern U.S. regions. (U.S. Dept. of Commerce and authors' estimates.
$S_{r,t}$	Volume of softwood lumber produced in region r, year t. (See previous source note.)
$ST_{r,t}$	Average cost of stumpage--U.S. regions only. (U.S. Forest Service and authors' estimates.)
TCC	Total Canadian softwood lumber consumption. (Statistics Canada.)

Table 1. (Continued)

Variable Name	Definition and (Source)
TUSC	Total U.S. softwood lumber consumption. (Derived from production and trade data--see other source notes.)
USDP	U.S. demand price: the average wholesale delivered price of lumber. (Average of mill prices plus transport costs from U.S. regions and Canada to U.S. delivery regions weighted by regional market shares in each delivery region and by total consumption across delivery regions. Market shares and delivery region consumption estimates from industry association shipments reports and authors' estimates. Transport costs from U.S. Dept. of Commerce and industry sources.)
USEX	Total U.S. softwood lumber exports. (U.S. Dept. of Commerce.)
USIO	U.S. imports of softwood lumber from countries other than Canada. (U.S. Dept. of Commerce.)
X	Real Canadian/U.S. exchange rate--nominal rate multiplied by the ratio of the U.S. all commodity producer price index (1967 = 1.0) to the Canadian producers' selling price index (1967 = 1.0). (International Monetary Fund and U.S. Bureau of Labor Statistics.)

Table 1. (Continued)

Notes:

a/ All U.S. price variables deflated by the all commodity producer price index and all Canadian price variables deflated by the Canadian producer selling price index, both with 1967 = 1.0.

b/ Regional index for U.S. regions = CO (Coastal), I (Interior), and S (South).

Table 2. Error measures from historical simulation, 1964-1983, Canadian-U.S. lumber trade model.[a/]

VARIABLE	AAPE	RMSE/MEAN
US CONSUMPTION	.066	.076
US DEMAND PRICE	.088	.098
REGIONAL PRICES		
COAST	.103	.015
INTERIOR	.111	.027
SOUTH	.097	.029
CANADA	.135	.024
REGIONAL OUTPUT		
COAST	.082	.129
INTERIOR	.062	.100
SOUTH	.100	.135
CANADA	.076	.087
STUMPAGE PRICES		
COAST	.185	.226
INTERIOR	.215	.234
SOUTH	.160	.184
CAPACITY		
COAST	.031	.041
INTERIOR	.054	.062
SOUTH	.108	.110
CANADA	.032	.034

a/ AAPE is the average absolute percentage error defined as:

$$AAPE = (1/n) \sum_{t=1}^{n} \left| (P_t - A_t)/A_t \right|$$

where A is the actual value, P is the model prediction, and n is the number of observations.

RMSE/MEAN is the root mean square error divided by the variable mean defined:

$$RMSE/MEAN = [(1/n) \sum_{t=1}^{n} (P_t - A_t)^2]^{0.5} / (1/n) \sum_{t=1}^{n} A_t$$

Table 3. Single and multi-period elasticities of endogenous variables with respect to exchange rate estimated under 1983, 1979, and 1975 market conditions.

VARIABLE	MEASUREMENT YEAR 1983 SINGLE	1983 MULTI	1979 SINGLE	1975 SINGLE
US DEMAND PRICE	-.35	-.07	-.38	-.33
US CONSUMPTION	.03	.17	.06	.03
LUMBER PRICES				
COAST	-.47	-.10	-.40	-.40
INTERIOR	-.43	-.09	-.43	-.46
SOUTH	-.39	-.08	-.41	-.40
CANADA	.76	1.15	.66	.81
LUMBER OUTPUT				
COAST	-.12	-.06	-.20	-.11
INTERIOR	-.13	-.03	-.19	-.10
SOUTH	-.05	-.02	-.14	-.08
CANADA	.24	.30	.39	.32
STUMPAGE PRICE				
COAST	-.45	-.04	-.28	-.31
INTERIOR	-.85	-.13	-.56	-1.06
SOUTH	-.52	-.09	-.50	-.67
CAPACITY				
COAST	-.03	-.01	-.04	-.02
INTERIOR	-.01	A/	-.03	-.03
SOUTH	-.02	A/	-.04	-.02
CANADA	.06	.09	.13	.08
CANADIAN SHARE OF US MARKET	.40	.23	.60	.63
US IMPORTS FROM CANADA	.44	.40	.66	.66

A/ Less than -.01.

Table 4. Changes from base simulation in 1979 resulting from imposition of a constant nominal exchange rate in the period 1975 through 1979

VARIABLE	% CHANGE FROM BASE IN 1979	ABSOLUTE CHANGE FROM BASE IN 1979
US DEMAND PRICE	+ 3.8 %	+ 5.78 $US/MBF
US CONSUMPTION	- 1.9	- 758 MMBF
COAST OUTPUT	+ 2.1	+ 245 MMBF
INTERIOR OUTPUT	+ 2.0	+ 134 MMBF
SOUTHERN OUTPUT	+ 1.3	+ 134 MMBF
CANADIAN OUTPUT	- 6.6	-1,270 MMBF
CANADIAN EXPORTS TO U.S.	-11.5	-1,270 MMBF
CANADIAN SHARE OF U.S. MARKET	- 9.8	- 2.7 %

FOOTNOTES

1/ The year 1975 presents some problems as a starting point for this simulation owning to strikes at lumber mills in the British Columbia coastal region. Output was restricted and Canadian market share probably reduced as a result. It should be noted, however, that Canadian share had been declining since 1973 following the downturn in U.S consumption, in a pattern similar to that observed in recessionary periods since 1950. Since U.S. consumption continued to decline in 1975, a reasonable conjecture is that Canadian share may have fallen less or perhaps stabilized at the 1974 level in the absence of the strike. In the latter, optimistic, case rebound from the strike would have accounted for only about a 1 percent share increase of the observed 7.5 percent expansion over the 1975-1979 period.

Figure 1. Canadian-U.S. exchange rate ($C/$US) and U.S. imports from Canada as a percent of total U.S. softwood lumber consumption (market share).

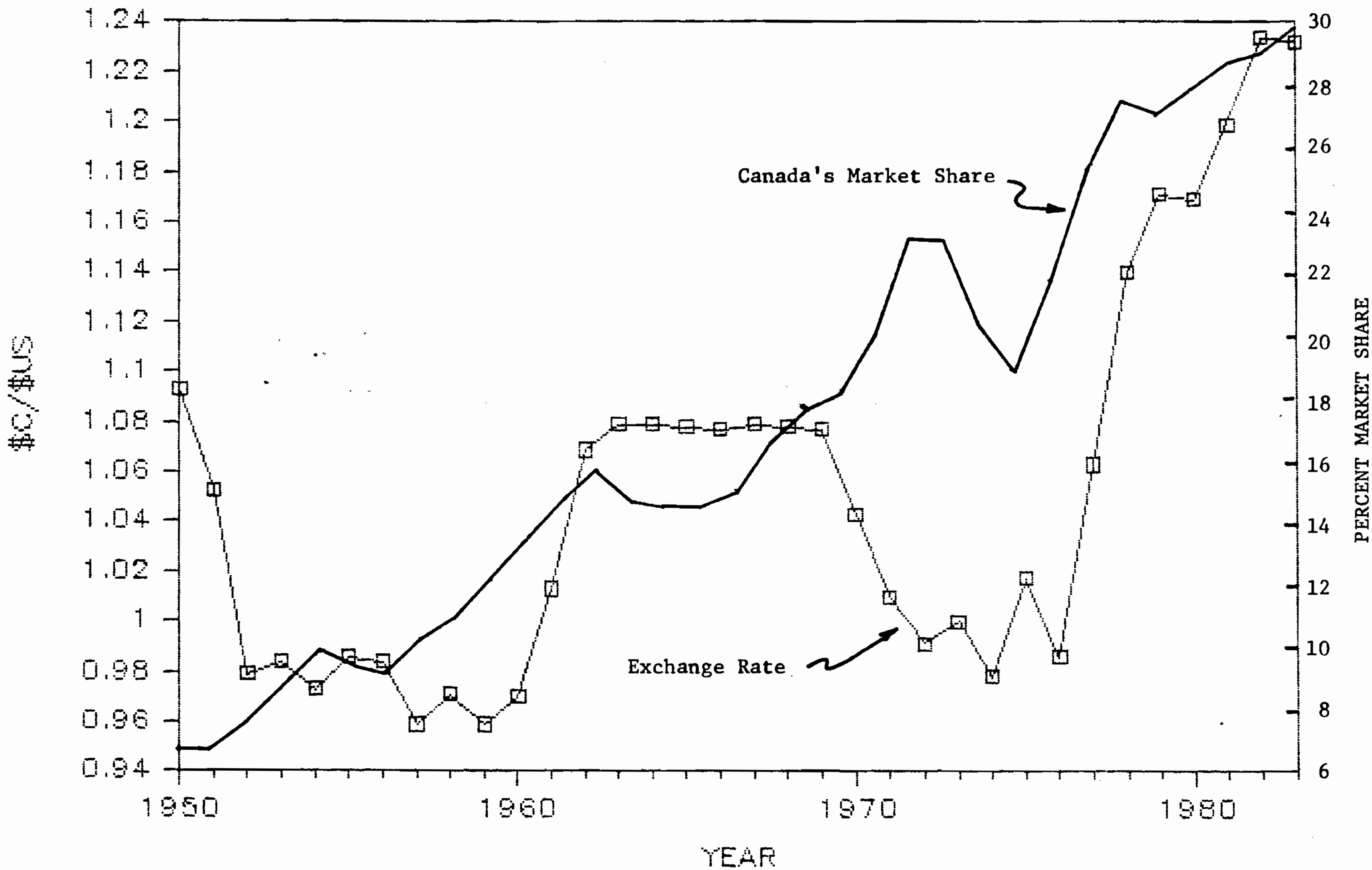

Figure 2a. Ratio of relative Canadian/US lumber cost growth to change in exchange rate (Condition (3) from text) and change in Canadian share of U.S. softwood lumber sonsumption.

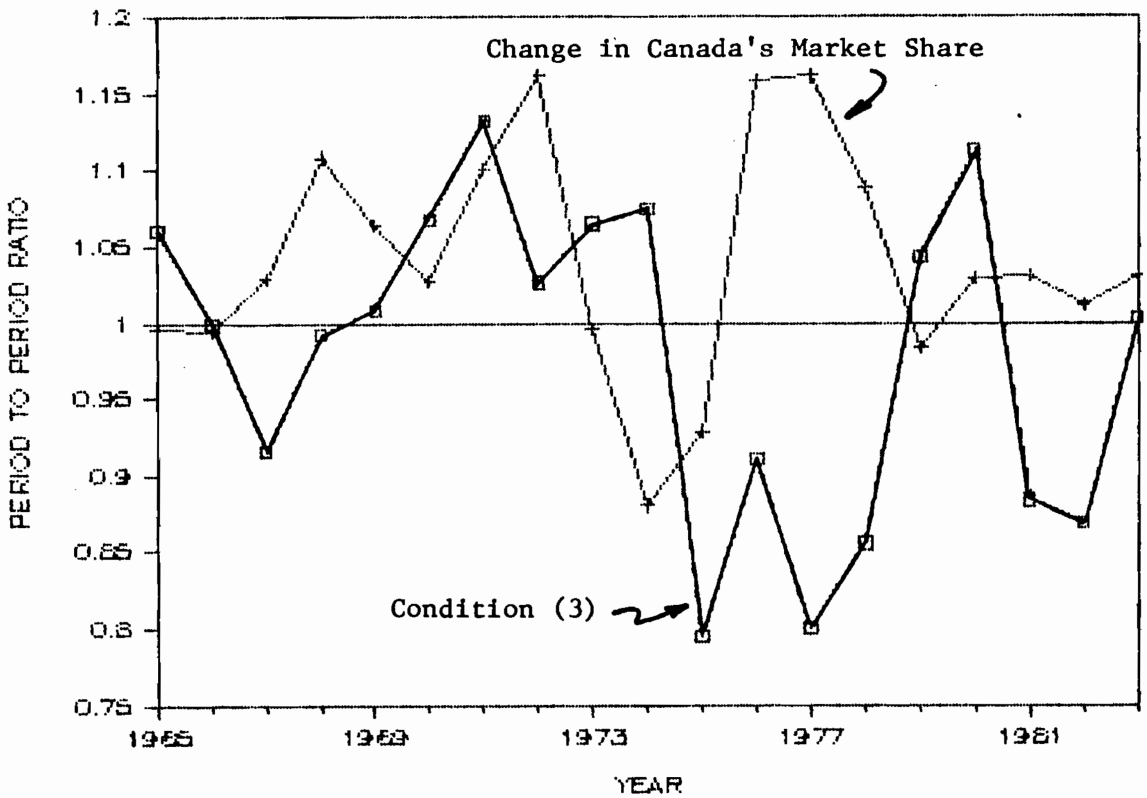

Figure 2b. Components of Condition (2) (see text): period-to-period change in relative Canadian/US lumber costs and exchange rate plotted with change in relative Canadian/US all commodity producer price indices.