AN ECONOMETRIC ANALYSIS OF MARKETS FOR CANADIAN LUMBER

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(Received June 1985)

ABSTRACT

An econometric model of markets for Canadian lumber has been developed and estimated from data for 33 years. Two equations for demand (domestic and export) and two for supply (domestic and import) were specified. Price elasticities of domestic demand and supply have been found to be inelastic. Per capita income appears to be the most important determinant of lumber consumption via its impact on housing demand in Canada. Housing starts in the United States determine most of the Canadian lumber exported to that country.

Keywords: Canadian lumber, market analysis, supply, demand, export, import.

INTRODUCTION

Long-range projection of forest products markets is of vital importance to management of forest resources because of the long period of time involved in growing trees. In a country like Canada, where forestry is so important in the economy,[1] it is surprising that there have not been nearly as many studies aimed at projecting demand into the future as in the United States. Manning (1970, 1975) and Aird and Ottens (1979) are the only published references on this subject in Canada,[2] while there are many in the United States (e.g., see McKillop 1967, 1969; Adams and Blackwell 1973; Robinson 1974; Adams and Haynes 1980).

Manning's pioneering attempts in Canada, though very useful, still have a few shortcomings. For example, in his 1975 study the role of the construction industry in the overall demand for lumber in Canada was not explicitly considered, though it happens to be the single most important user of lumber in the United States (McKillop 1967; Adams and Blackwell 1973) and presumably, therefore, in Canada also. Similarly, Aird and Ottens (1979) have given an overall view of timber utilization to the year 2000. However, many of the demand and supply relationships, and projections based on them, were estimated directly from single equations. When the objective is to study underlying relationships as well as the construction of better forecasting instruments, however, a system of simultaneous equations is considered to be more appropriate (Holland 1970). Further, neither of these two studies provides any validity checks for the results of their forecasts.

This paper presents a simple annual market model of supply and demand for Canadian lumber that attempts to deal with the above shortcomings. It has also been projected into the future up to the year 2000. Demand in this model includes both domestic and export components. The latter originates mainly in the United

[1] Some 13% of all persons employed in manufacturing are in forestry, and the sector contributes 15 cents of every dollar of direct value added in all Canadian manufacturing (Aird and Ottens 1979).

[2] An attempt to estimate the derived demand for roundwood faced by Ontario forest products industry has been made by Nautiyal and Singh (1983).

Wood and Fiber Science, 18(3), 1986, pp. 382–396

States, where about 80% of all Canadian softwood lumber is marketed (Aird and Ottens 1979). Similarly, supply in the model includes both imports and domestic sources.

THE MODEL

As in all econometric analyses, the basic assumption in the construction of the present model is that the marketing of lumber can well be expressed by a system of simultaneous linear equations.

The process of model construction and identification consists of specifying and testing a set of predetermined variables that would explain the part of the shifts not already accounted for by the endogenous variables appearing in the system. For choosing among alternative specifications, a two-step procedure was employed. First, a given set of plausible variables was assigned to each relation in the basic structure in accordance with economic theory. Any two variables with a simple correlation coefficient of 0.90 or higher were reconsidered (Foot and North 1977) and only the one having higher correlation with the dependent variable was retained. In the next step, when the model was specified with a few variables on the right-hand side of each relation, two criteria were used in finalizing it. The first criterion was to see that the sign of the coefficient of each variable was consistent with economic theory. The second criterion was to check for the statistical significance of the coefficients as shown by the t statistic.

The resulting model consisted of six interdependent relations, one for each endogenous variable, describing the structure of the Canadian lumber markets. Each of these relations is given below with variables appearing in it. There may be some "cause and effect" relationships here, but we make no attempt to identify them and remain confined to examination of association between dependent and independent variables. For convenience, the acronyms of all endogenous variables are in capital letters, while those of the exogenous variables have only the first two letters in upper case.

1. Quantity of lumber demanded in Canada (QLDC) in a year, which depends on:
   (i) Housing starts in Canada (HHsc);
   (ii) Per capita income in Canada (PCic);
   (iii) Prices of building materials in Canada (PBmc).
2. Quantity of Canadian lumber exported to the United States (QLES) in a year, which depends on:
   (i) Housing Starts in the United States (HSus);
   (ii) Quantity of Canadian lumber exported to countries other than the United States (LEOC);
   (iii) Price of lumber in the United States (PLus);
   (iv) A measure of the difference in price of lumber in the United States and price paid to Canadian exporters by the U.S. (DPsc).
3. Quantity of Canadian lumber exported to countries other than the United States (LEOC) in a year, which by definition is the:
   (i) Total lumber supply available in Canada (QLSC), *minus*
   (ii) Quantity of lumber demanded in Canada (QLDC), *minus*
   (iii) Quantity of lumber exported to the United States (QLES).

4. Quantity of lumber imported into Canada (QLIC) in a year, which depends on:
   (i) Quantity of lumber demanded in Canada (QLDC);
   (ii) Price of lumber in Canada (PIlc);
   (iii) Exchange rate of Canadian dollar to the U.S. dollar (EXcs).
5. Quantity of lumber produced in Canada (QLPC) in a year, which depends on:
   (i) Price of lumber in Canada (PIlc);
   (ii) Wage rate in the lumber industry, lagged one year, ($WRli_{t-1}$);
   (iii) Ratio of capital to labor in the lumber industry (RCll).
6. Total quantity of lumber supply available in Canada (QLSC) for domestic consumption and exports in a year, which by definition is the:
   (i) Quantity of lumber produced in Canada (QLPC), *plus*
   (ii) Quantity of lumber imported into Canada (QLIC).

It is clear that the relations 1, 2, 4 and 5 above describe the behavior of the lumber market, while 3 and 6 are accounting identities. The latter are included to provide extra information that is helpful in computing the reduced form coefficients. The basic difference between the two sets of equations is that while the behavioral equations contain parameters and stochastic terms, the identities are free of any parameters and are nonstochastic. For ease of reference, the definition for each variable in the structural equations is given in Table 1 (in alphabetical order) with the sources of information. Figure 1 shows the interrelationships of all the exogenous and endogenous variables in the model in the form of a flow chart. Each of the relationships is further discussed in the following paragraphs with justifications for the variables appearing in them.

The domestic demand relationship in Eq. 1 is straightforward. A component of the demand depends on housing starts (HHsc) and per capita income (PCic) in Canada. One might have expected that price of lumber would also appear in this relationship. However, in the second step of choosing among specifications, described earlier, this variable was not only found to be insignificant but its coefficient had the wrong sign. Alternatively, an index of residential building material prices (PBmc) was considered in the equation which was not only significant but of the correct sign. Since lumber is an important input in residential building construction, this index should reflect not only the price of lumber but also other material inputs that may significantly affect the demand for lumber. Price of lumber was insignificant in the model of Manning (1975) also. The possible reasons for this rather unexpected observation are discussed later in this paper. Housing starts (HHsc) can be measured in several items such as detached and semi-detached houses, apartments, and industrial buildings. After some trial and error, we found that lumber demand was correlated most strongly with the number of detached and semi-detached residential units. Construction of industrial and apartment buildings in Canada did not show any strong relationship with lumber consumption. Therefore, for the purposes of this study we have taken HHsc to mean the number of detached and semi-detached residential units in Canada.

Given that the United States is the main market for Canadian lumber in Eq. 2, quantity exported to the United States (QLES) is endogenous in the system. Housing starts (HSus) and price of lumber in the United States (PLus) were found to be strongly related to the U.S. imports of Canadian lumber. Also, a measure

TABLE 1. *Description of variables and their sources of information.*

Variable	Description and source of information
DPsc	PLus minus Canadian lumber price in the U.S. market. The latter was obtained as average value of export adjusted for exchange rate between the two countries and then deflated by the U.S. wholesale price index to make it comparable to the variable PLus. Quantities exported and values were obtained from Statistics Canada, Cat. No. 65-202 (annual).
EXcs	Exchange rate of U.S. dollar for the Canadian dollar taken to be the amount of Canadian currency equivalent to one hundred U.S. dollars. Source: Bank of Canada Review (annual).
HHsc	Housing starts in Canada (detached and semi-detached units in thousands). Source: Statistics Canada, Cat. No. 64-002 (annual).
HSus	Housing starts in the United States (in thousands). Source: Statistical Abstract of the United States (annual).
LEOC	Quantity of lumber exported to countries other than the United States (million cubic meters) derived as: QLSC-QLDC-QLES. Sources: Statistics Canada, Cat. Numbers 35-204 (annual), 25-505 (occasional), 65-202 (annual) and 65-203 (annual).
PBmc	Price index of residential building material (1971 = 100). Source: Statistics Canada, Cat. No. 62-007 (annual).
PCic	Per capita income of Canada (thousand dollars). Source: Statistics Canada, Cat. No. 13-201 (annual).
PIlc	Price index of lumber in Canada (1971 = 100). Source: Statistics Canada, Cat. No. 62-011 (annual).
PLus	Price index of all lumber in the United States (1967 = 100) deflated by the wholesale price index of all commodities (1967 = 100). Sources: The demand and price situation for forest products (U.S. Department of Agriculture, Forest Service), Historical Series of the United States, Colonial times to 1970 (part 1) and Statistical Abstract of the United States (annual).
QLDC	Quantity of lumber demanded in Canada measured as apparent consumption: QLSC-QLES-LEOC (million cubic meters). Sources: Statistics Canada, Cat. Numbers 35-204 (annual), 25-505 (occasional), 65-202 (annual) and 65-203 (annual).
QLES	Quantity of lumber (in million cubic meters) exported to the United States. Source: Statistics Canada, Cat. No. 65-202 (annual).
QLIC	Quantity of lumber (in million cubic meters) imported into Canada. Source: Statistics Canada, Cat. No. 65-202 (annual).
QLPC	Total lumber production in Canada (in million cubic meters). Source: Statistics Canada, Cat. No. 35-204 (annual) and 25-504 (occasional).
QLSC	Total lumber supply in Canada derived as QLPC + QLIC (million cubic meters). Sources: Statistics Canada, Cat. Numbers 35-204 (annual), 25-505 (occasional) and 65-203 (annual).
RCIl	Capital per person employed in the lumber industry. Sources: Statistics Canada, Cat. Numbers 35-204 (annual) and 67-002 (annual).
WRli	Price of labor (lagged one year, in dollar per worker per year) derived by dividing the total salaries and wages by the total man-hours paid in the industry. Source: Statistics Canada, Cat. No. 35-204 (annual).

of the difference in the U.S. lumber price and of Canadian lumber in the U.S. market (DPsc) was found strongly and positively related to the quantities of lumber imported from Canada. Further, the U.S. market cannot be taken in isolation of the Canadian and other world markets. In view of this fact the quantity of lumber exported to other countries (LEOC) was added in this equation. The LEOC as an

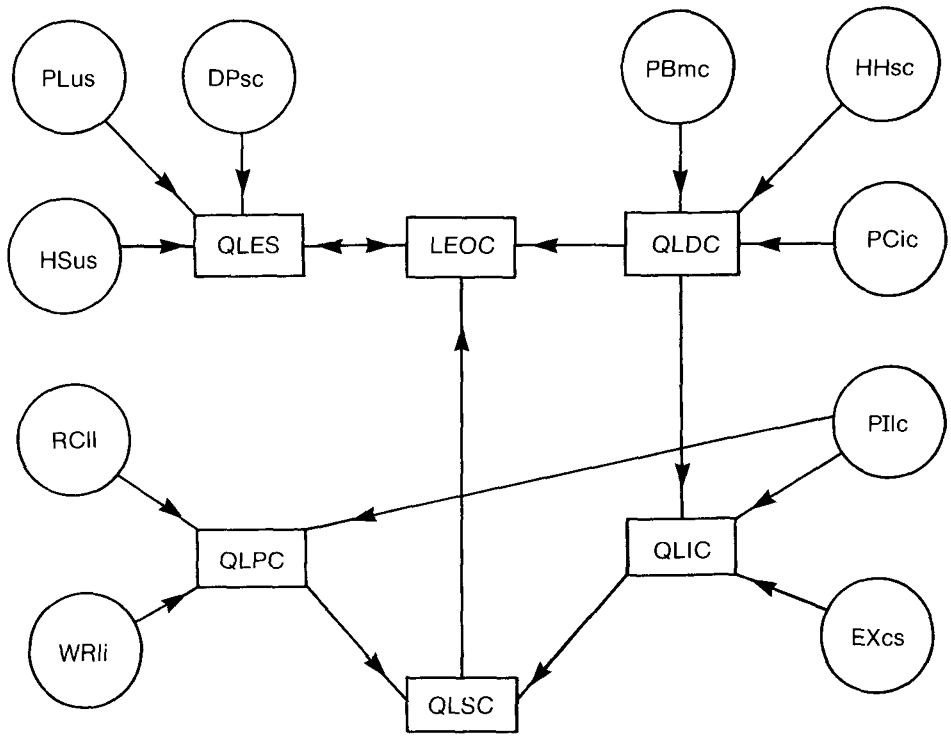

FIG. 1. Flow diagram of the Canadian lumber market model. Notes: (a) Exogenous variables are circled and endogenous put inside boxes. (b) Direction of an arrow is always from an independent variable to a dependent variable.

independent variable in the equation would capture the effects of all the domestic Canadian demand and supply conditions on its exports to the United States.

The LEOC has been expressed through an identity in Eq. 3. Thus, the quantity of lumber exported to other countries has been treated as the residual of domestic consumption and exports to the United States. In other words, these exports have been assumed to be determined solely by the conditions prevailing in the Canadian and U.S. markets and not on those in distant markets. This was done simply because modelling foreign markets other than the United States was beyond the scope of this study and also because these exports form only a minor part of total Canadian lumber exports.

The supply of lumber has been specified separately for the imported and domestic sources in Eqs. 4 and 5, respectively. An increasing trend of lumber imports (mainly hardwood) over the years was observed, which comes mainly from the United States. Inclusion of this source of supply (QLIC) was, therefore, necessary in Eq. 4. It was found to be dependent on the domestic lumber consumption (QLDC), domestic lumber price (PIlc), and the exchange rate of Canadian dollar to the United States dollar (EXcs).

Equation 5 is the domestic supply of lumber (QLPC), which has been measured as the total lumber produced in Canada in a year. Since in a supply equation variables representing costs of factors of production must be included, factor prices of both labor and roundwood were considered at the first stage of model construction as described earlier. Labor and roundwood are the most important factors of production of lumber in terms of shares in total cost of production (Nautiyal and Singh 1985). While the coefficients of both price variables were negative as expected, the coefficient associated with roundwood price (current as well as one year lagged) was not significantly different from zero even at the 10% level of significance. This coefficient was also not found significantly different from zero in softwood lumber supply equation of Manning (1975). The coefficient of lagged price of labor ($WRli_{t-1}$), however, was highly significant and was retained in the equation. The second variable in this equation was price of lumber (PIlc) and was found significantly related to the lumber supply. The third, and the last, variable in this equation was the ratio of labor to capital (RCll) in the lumber industry. This variable was included in the hope that it would capture the technical advancements that might have occurred in the industry over the sample period. It is difficult to get some direct measure of influence of technological progress in the supply equation. An obvious measure (output/labor ratio or output/capital ratio) was ruled out because it would be correlated with the dependent variable, the output. Alternatively, the ratio of capital to labor was included as a surrogate measure of labor productivity. For most practical purposes, this variable would measure the impact of increased labor productivity due to capital deepening in the industry. This variable can be of importance for policy formulation and will answer the question whether the lumber industry, which has been primarily labor intensive in the past years, should favor the replacement of labor with capital to increase output and create excess supply in the export market.

The last equation (Eq. 6) is an identity and states that total lumber supply in Canada (QLSC) is the sum of domestically produced lumber (QLPC) and quantities imported (QLIC). This total supply is used in domestic consumption, exports to the United States, and exports to other countries. It has been assumed here that quantity imported into Canada can be re-exported.

Data for a period of 33 years (1950 to 1982) were used to estimate the structural coefficients of the equations and the elasticities of quantities demanded and supplied, with respect to the variables determining them. As ordinary least-squares estimates of either of the equations will, in general, yield biased and inconsistent estimates of structural coefficients (Rao and Miller 1971; Johnston 1984), the two stage least-squares estimation procedure was adopted. Our primary objective was to obtain unbiased and consistent estimates of the parameters.

RESULTS AND DISCUSSION

The problem of multicollinearity is quite common in econometric analyses and was encountered in this study also. Preliminary regressions were started with 31 predetermined variables in the system, but final specification contained only 10 variables. Surprisingly, the problem of auto-correlation was not very serious in the present model as it is in most time-series analyses. The test of auto-correlation parameter indicated that it was not different from zero even at the 5% level of significance in 3 out of 4 stochastic equations. Some degree of auto-correlation, however, was present in the import equation (Eq. 4). Auto-correlation was removed from this equation following the method suggested by Fair (1970).

Table 2 presents the estimated coefficients of the structural equations along

TABLE 2. *Estimated coefficients and elasticities for the behavioral equations, Canadian lumber industry, 1950–1982.*

Equation	Independent variable	Regression coefficient	Standard error	Student's *t* statistics	Point estimates of elasticities
1. Quantity of lumber demanded in Canada (QLDC)	Intercept	5.7679	2.9078	1.98**	—
	HHsc	0.0202	0.0100	1.99**	0.2149
	PCic	0.0051	0.0026	1.96*	1.6808
	PBmc	−0.0547	0.0245	2.23**	0.5842
		$R^2 = 0.94$	Durbin-Watson = 1.84		
2. Quantity of lumber exported to the United States (QLES)	Intercept	−6.3257	3.4534	1.78*	—
	LEOC	0.4169	0.1931	2.13**	0.1436
	HSus	0.0113	0.0018	6.27***	1.2420
	PLus	0.0478	0.0067	7.13***	0.5619
	DPsc	0.3260	0.1227	2.65***	0.5662
		$R^2 = 0.93$	Durbin-Watson = 1.96		
3. Quantity of lumber imported into Canada (QLIC)	Intercept	0.2683	0.1289	2.08**	—
	QLDC	0.0310	0.0112	2.76***	0.4562
	PIlc	0.0061	0.0018	3.38***	0.5913
	EXcs	−0.0086	0.0042	2.04**	1.3506
		$R^2 = 0.92$	Durbin-Watson = 1.94		
4. Quantity of lumber produced in Canada (QLPC)	Intercept	8.7463	5.7123	1.53	—
	PIlc	0.1169	0.0250	4.66***	0.5177
	$WRli_{t-1}$	−0.3329	0.1170	2.84***	0.1725
	RCll	0.7809	0.2001	3.92***	0.5902
		$R^2 = 0.96$	Durbin-Watson = 1.86		

Note: A single asterisk indicates significance at the 10% level, a double asterisk at the 5% level and a triple asterisk at the 1% level.

with their standard errors of estimate, coefficients of multiple determination (R^2), Durbin-Watson Statistics and point estimates of elasticity. The values of R^2 and the standard errors indicate the degree of the success attained in estimating the model. Most coefficients are significantly different from zero at very high levels of probability. In many cases, the standard errors of estimates are extremely low. The adjusted R^2s are higher than 0.90 in each estimated equation.

As noted from Table 2 all estimated structural coefficients have signs that could be expected on the basis of common ideas and in accordance with economic theory. In the domestic demand equation (Eq. 1), housing starts (HHsc) and per capita income (PCic) have the normally expected positive impact on lumber consumption. An increase in the price of building materials (PBmc), on the other hand, decreases the lumber consumption.

A more important finding of the model is that there is a positive relationship between price in the U.S. market and the volume of exports from Canada to the U.S. (Eq. 2). This is a confirmation of Darr's (1981) hypothesis, and makes sense because as domestic prices in the U.S. rise there will be a tendency to import more from Canada, its largest trading partner in lumber, as long as the import prices remain lower than the U.S. prices. The high significance of the coefficient of a measure of the difference between the two prices (i.e., of the coefficient DPsc) underscores this point. The positive sign of this coefficient suggests that as U.S. prices have risen over the years, prices paid to Canadians for their lumber have not risen that fast.

The observed positive associations of volume of exports with the price in the U.S. market (PLus) or with the difference in the two prices (DPsc) might occur under any of the following conditions: (1) Domestic demand for lumber in Canada does not shift, while a decrease in domestic supply increases lumber price in the export market. And, at the same time, demand in the United States increases even more. (2) Domestic demand of lumber in Canada increases with no shift in supply. But, at the same time, U.S. demand increases even more. (3) Domestic supply of lumber in the United States does not increase. An increase in U.S. lumber demand increases price and volume of imports.

Since domestic supply of lumber in Canada has increased substantially in the past years (from 18.91 million cubic meters in 1960 to 40.22 million cubic meters in 1981), the first two conditions above are not met. It appears that the observed positive association of price and volume of export has resulted from the last condition mentioned above. That is, while demand in the United States has increased, supply there has remained stagnant (U.S. lumber production decreased from 77.7 million cubic meters (32.92 billion bd ft) in 1960 to 67.65 million cubic meters (28.62 billion bd ft) in 1981. The export equation in Table 2, therefore, may simply be taken as the supply equation for the United States. A positive response of this supply to price is thus quite natural.

The domestic price of lumber (PIlc) has positive impact on both the domestic as well as imported sources of supply while the lagged price of labor input ($WRli_{t-1}$) has a negative impact on the domestic supply. The rate of exchange (EXcs) affects the quantity of lumber imported adversely. These results are consistent with the theory of supply. The high significance of coefficient of the productivity variable (RCll) indicates the impact of a discernible gain in productivity due to automation in Canadian sawmills, a result that supports the finding of Sandoe and Wayman (1977). Due to rising wages, sawmills seem to have gradually favored substitution of machinery (capital) for labor by adopting increased automation and thus experienced improved labor productivity. This conclusion appears to be consistent with Nautiyal and Singh (1985) that there has been some substitution of capital with labor and that the share of labor in the total cost of production in the industry has decreased over the years.

The coefficients of elasticity provide a means by which the independent variables may be ranked with regard to their relative importance (McKillop 1967). The elasticity coefficients measure the proportional change in each dependent variable due to corresponding proportional change in the independent variables in the equations. Thus, the elasticity coefficients reflect the strength of the independent variables to affect the dependent variable in an equation. In the domestic demand equation (Eq. 1), for example, the point estimates of elasticity, presented in Table 2, suggest that per capita income (PCic) is the most important factor affecting the lumber demand. Similarly, in the case of the export and import equations, number of housing starts in the United States (HSus) and exchange rate (EXcs) are the most important factors determining any change in the volume of exports and imports, respectively. Effect of factors other than the most important in any equation is slight.

In the domestic demand equation (Eq. 1), absence of its own price, as noted earlier, suggests that demand is infinitely price inelastic. However, significance of the surrogate price variable (PBmc) suggests that lumber price affects its consumption indirectly in combination with prices of other building construction materials. This also suggests that there are complementarities between the demand for lumber and other materials in housing construction. Lumber is used mainly in construction and repair works where its cost is a minor proportion of the total expenditure for construction (McKillop 1967). Therefore, quantity of lumber demanded is little affected by its own price. Even in conjunction with the prices of other related construction materials, its effect is slight as is indicated by the low elasticity coefficient of the variable PBmc.

Supply from imported sources is price inelastic in Eq. 4. This result is very understandable because lumber import into Canada constitutes only a minor portion of the total supply. On the other hand, quantity imported has an elastic response to exchange rate changes. Such quantity tends to decrease as value of the Canadian dollar falls in relation to the U.S. dollar. This result is again quite natural. As a result of unfavorable exchange rate to Canada, the price at which lumber can be imported would increase. If imports are a substantial proportion of total supply, their higher price will tend to increase the price of all lumber in Canada. Therefore, a better assessment of price response of quantity imported would have been made if the import price, rather than the domestic price were used in the equation. The analysis, then, would have been parallel to the treatment of demand in Eq. 2. However, this was not done because imports were such a small part of supply that no significant policy implications were involved. In any case, our model indicates that quantity of lumber imports increases with the increase in domestic price and level of consumption.

Supply from domestic source is also price inelastic in Eq. 5. This result is in accordance with the expected long-run nature of wood supply. It should be remembered that price response of lumber supply depends not only on the production process of converting roundwood into lumber but also on the factors that determine the cost at which roundwood becomes available to the sawmills. In addition, there are severe limitations on the expansion of wood supply in the long run because of well-accepted forest management principles, such as sustained yield. As pointed out by Zivnuska (1949), timber supply is less elastic in the long-run than in the short run. In fact, it can be shown that in a forest management model with fixed land area and intensity of management, the long-run supply schedule of timber may not merely be inelastic but even downward sloping (Clark 1976, p. 263). In the short run also, the supply from managed forests is less elastic than from unmanaged forest, since the essence of forest management is control of the rate of cutting by physical criteria rather than by exclusive market criteria (Zivnuska 1955). Further, as stated by Holland (1960), Zaremba (1961), and Mead (1964), a decline in size and quality of stumpage and increasing distance to the mills may cause the supply to be less responsive to market conditions. The empirically determined elastic response by McKillop (1967), Adams and Blackwell (1973), and Robinson (1974) may be due to the short-run ability of the forest industries to adjust supplies to the shifts in lumber demand and, it may be added, due to the so-called Allowable Cut Effect (Schweitzer et al. 1972) if it was applicable. As concluded by Robinson (1974) for the United States, such achievement may also be due to productivity gains (Kaiser 1971) in the industry, which permit harvesting of more distant timber without too much increase in cost. Our model also indicates such gain in productivity of labor as indicated by the positive and high significance of the coefficient of variable RCll in this equation. Productivity gains in the logging industry (Morrison and Halpern 1975) and in forest industries (Sandoe and Wayman 1977) have also been indicated. It appears that such gains have been partly eroded by the declining quality of roundwood in the lumber industry (Singh and Nautiyal 1986). Thus, supply of timber and hence lumber cannot be expected to be price elastic in Canada.

FORECAST

In addition to providing information directly from the estimated structure the model can also be used for forecasting the future magnitudes of the endogenous variables. Such forecasts, however, are often quite subjective and seldom free of error. The main problem is the distortion of the true relations among variables due to random influence of other variables not taken into account in the prediction equations, thus creating a cumulative error that can invalidate the forecasts. In spite of such risks, the present model has been used to forecast the values of the endogenous varibles to the year 2000.

Before predictions of the endogenous variables can be made, forecasts of the values of exogenous variables are required. For this purpose, the trends of exogenous variables were plotted against time. The linear, quadratic, and logarithmic forms were fitted by the least-squares method using data from 1950 to 1982. The best fitting trend, indicated by the coefficients of multiple determination (R^2), was chosen for extrapolations. Strong quadratic trends for most of the variables were found. Table 3 presents the results of the least-squares estimates of the linear and quadratic trend coefficients. The linear and logarithmic linear forms yielded comparable R^2, so results for the former only are being presented. It can be seen from this table that good estimates of the trends of the past values of exogenous variables are obtained in most of the cases with significant linear and quadratic relations and substantially high R^2 in general. However, the R^2's of the quadratic trend fitting are higher in all cases except for two variables DPsc and PCic. Therefore, the quadratic coefficients were used for extrapolating all variables except the two mentioned above. Extrapolations of the latter two variables were based on the linear trend coefficients.

The Durbin-Watson of the fitted trend equations indicated that auto-correlation was present in all equations. Under such a situation forecasts of the variables will be inconsistent. To overcome this problem the forecasts were made including a first order serial correlation correction using the estimated values of ρ from the previous regressions. The program for such forecasting is available in the Time Series Processor (version 3.5). The extrapolation so obtained can be treated to be a dynamic forecast because it takes the lagged values of variables into account. The forecasted values of exogenous variables and the corresponding hypothesized forecasts of each endogenous variable are presented in Table 4 for the years 1985, 1990, 1995 and 2000.

SAMPLE PERIOD SIMULATION

The predictive ability of the estimated model and forecasts of the endogenous variables based on it were investigated by simulating each equation over the sample period. Among the many ends of such a procedure is that it enables one to isolate the magnitude of forecasting error that may result from using the model

TABLE 3. *Results of regression of exogenous variables on time, 1950–1982.*

Variables and forms of function	Intercept	Coefficient of T	Coefficient of T^2	R^2
DPsc				
Linear	−2.0771	1.4556*** (0.4556)	—	0.55
Quadratic	4.4068	0.3441 (0.8876)	0.0326 (0.0538)	0.25
EXcs				
Linear	97.61	0.4245*** (0.1106)	—	0.64
Quadratic	104.58	−0.7661* (0.4056)	0.0350*** (0.0115)	0.76
HHsc				
Linear	70.18	1.6860*** (0.3459)	—	0.43
Quadratic	65.98	2.4128*** (0.4426)	−0.0213* (0.0116)	0.56
HSus				
Linear	1,197.20	15.4044*** (5.5520)	—	0.40
Quadratic	958.66	56.3909*** (21.9420)	−1.2057* (0.6260)	0.54
PBmc				
Linear	22.16	5.1084*** (0.5156)	—	0.76
Quadratic	85.35	−5.7139*** (0.7188)	0.3183*** (0.0205)	0.97
PCic				
Linear	−3.81	2.2123*** (0.1734)	—	0.84
Quadratic	13.34	−0.7288* (0.3704)	0.0864*** (0.0132)	0.93
PIlc				
Linear	28.50	5.2172*** (0.6030)	—	0.71
Quadratic	90.26	−5.3696*** (1.5527)	0.3113*** (0.0440)	0.88
PLus				
Linear	107.02	−0.0939 (0.1575)	—	0.11
Quadratic	121.09	−2.5055*** (0.4789)	0.0709*** (0.0136)	0.48
RCll				
Linear	−0.2816	0.6305*** (0.2018)	—	0.92
Quadratic	4.1520	−0.1305 (0.1683)	0.0223*** (0.0048)	0.82

TABLE 3. *Continued.*

Variables and forms of function	Intercept	Coefficient of T	Coefficient of T^2	R^2
WRli				
Linear	−1.3271	0.2911*** (0.0299)	—	0.75
Quadratic	2.27	−0.3298** (0.1208)	0.0181*** (0.0013)	0.96

Notes: Figures in parentheses are the standard error of estimates. A single asterisk indicates significance at the 10% level, a double asterisk at the 5% level and a triple asterisk at the 1% level.

(Haitovisky et al. 1974). That is, one can see how well the model has been able to forecast and have some idea of the degree of uncertainty of the values of endogenous variables in the forecast period.

The simulation procedure required obtaining the reduced form of the model and using the coefficients to solve and simulate each equation over the entire sample period. The results were expressed in two performance measures: Inequality Coefficient (U) and Absolute Percentage Error Index (EI).

The Inequality Coefficient (U) appraises the quality of the directional change estimates. It is defined by Theil (1966)[3] as:

$$U = \left[\sum_{i=2}^{T} (P_{ij} - A_{ij})^2 \Big/ \sum_{i=2}^{T} A_{ij}{}^2 \right]^{1/2}$$

where

P_{ij} = the estimated change in the value of the j-th variable in the i-th time period.

A_{ij} = the observed change in the value of the j-th variable in the i-th time period.

The numerator of the above expression is the root-mean-square prediction error and the denominator the root-mean-square observed changes. Thus the above definition compares the forecasts and no-change extrapolation in terms of root-mean-square prediction error. It will be seen that $U = 0$ only if the forecasts are all perfect ($P_{ij} = A_{ij}$). Also, $U = 1$ when the prediction is such that it yields the same root-mean-square error as that based on extrapolation on no-change basis. It is clear from the above that the Inequality Coefficient has no finite upper bound, which implies that it is possible to do considerably worse than by just extrapolating on a no-change basis.

The Percentage Error Index (EI) provides a measure of the average matching of the endogenous variable vectors of the estimated and the actual values over the T time periods. The index of each endogenous variable is estimated over the sample period as the absolute value of difference between the estimated and observed value divided by the observed value. Robinson (1974) has expressed the index as:

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[3] An earlier definition of Inequality Coefficient was also proposed by Theil (1960). However, in 1966 he suggested that the definition used here is superior to the earlier one.

TABLE 4. *Forecasts of the exogenous and the endogenous variables to the year 1985, 1990, 1995 and 2000.*

Variable	1985	1990	1995	2000
Exogenous variables				
DPsc (index)	48.86	53.24	60.52	67.79
EXcs (hundred Can. $)	135.24	136.35	138.23	144.46
HHsc (thousand)	124.23	126.80	130.58	132.58
HSus (thousand)	1,462.60	1,369.00	1,165.30	1,032.00
PBmc (index)	275.42	329.99	368.35	408.63
PCic (thousand Can. $)	9.13	12.98	14.09	17.63
PIlc (index)	283.68	335.75	380.98	434.78
PLus (index)	205.56	221.11	249.86	282.18
RCll (thousand Can. $)	26.91	31.41	39.79	49.28
WRli (Can. $ per h)	12.89	15.86	21.54	24.13
Endogenous variables				
QLDC (million m^3)	12.42	14.98	18.43	20.07
QLES (million m^3)	20.67	20.34	17.32	16.84
LEOC (million m^3)	8.53	9.02	12.16	16.52
QLIC (million m^3)	1.34	1.86	2.30	2.97
QLPC (million m^3)	40.28	42.48	45.61	50.46
QLSC (million m^3)	41.62	44.34	47.91	53.43

Note: Forecasts of the endogenous variables are based on the reduced forms of equations.

$$EI = \left[\sum_{i=1}^{T} (E_{ij} - O_{ij}) \Big/ \sum_{i=1}^{T} O_{ij} \right] \times 100$$

where

E_{ij} = the estimated value of the j-th endogenous variable for the i-th time period.

O_{ij} = the observed value of the j-th endogenous variable for the i-th time period.

The index can range from zero to one and an index of zero would indicate a perfect forecast. These two performance measures are presented in Table 3 for each endogenous variable.

Results in Table 3 indicate that estimates based on the sample period of 33 years yield a percentage error index and an inequality coefficient of 10.63 and 0.77, respectively, for the model as a whole. Thus an average error of 10.63% may be expected in model estimation. The inequality coefficient of 0.77 for the model as a whole indicates superiority of the variable change estimation over no-

TABLE 5. *Inequality coefficient (U) and percentage error index (EI) for each endogenous variable.*

Variable	U	EI
1. QLDC	0.93	8.56
2. QLES	0.58	11.66
3. QLIC	0.72	17.16
4. QLPC	0.84	5.21
All	0.77	10.63

change extrapolation. Though the equation for imported supply indicates an 18.34% error, the inequality coefficient shows that it is superior to the no-change prediction. However, the inequality coefficient for the domestic demand equation indicates only a slight gain over the no-change extrapolation.

CONCLUSIONS AND POLICY IMPLICATIONS

The conclusions and policy implications of this aggregate (soft and hardwood) Canadian lumber industry model can be summarized as follows.

1. Domestic lumber demand depends primarily on the demand for housing and the level of per capita income in the country. A policy designed to improve general economic conditions would therefore promote the lumber industry.

2. The significant positive relationship between quantities of lumber exported and price in the export market (the United States) suggests that demand for lumber in the United States is an important determinant of price and volume of exports. The quantity exported tends to increase when the U.S. lumber price increases or as the difference between domestic U.S. price and price at which the U.S. can import Canadian lumber increases. Further, the total demand for Canadian lumber is determined more by the housing starts in the United States than in Canada. Thus, if domestic demand remains stable, there are ample opportunities for exporting lumber to the United States through aggressive marketing efforts when U.S. housing starts are increasing or by making Canadian lumber cheaper than the domestically produced U.S. lumber. The decline in the export of Canadian lumber to U.S. since the peak 1978 can be partly attributed to the decline in the U.S. housing starts, which is further expected to drop if past trends continue. The quantity of exports to the United States is also expected to decline in the next 15 years. Canada should, therefore, increase its efforts at finding new markets for its lumber in other parts of the world.

3. Capital deepening is an important variable in the domestic supply equation. This deepening has occurred with the modernization of sawmilling operations in the last 33 years. Further investment in new capital intensive technology is an important issue if Canada is to maintain and possibly improve its competitive position in international trade. With such modernization of sawmills, increased exports can be made without much increase in cost of production.

4. Cost of logs does not appear to reduce supply of lumber. Logging economically more inaccessible areas may not be such a significant constraint to increased lumber production in Canada as might be generally believed. On the other hand, cost of labor affects the output level of the industry negatively and significantly. Replacement of labor, which is becoming more and more costly, is thus important. This can be done only by modernization of sawmills. It seems that labor is a more important input likely to create a bottleneck in the industry than roundwood.

ACKNOWLEDGMENTS

The authors wish to thank Professor David K. Foot, Department of Economics, University of Toronto, Professor Joseph G. Massey, Department of Forest Science, Texas A&M University, and Dr. James E. Granskog, Southern Forest Experiment Station, U.S. Forest Service, for reviewing this paper and giving some valuable suggestions. The authors, of course, assume all responsibilities for any remaining errors. Financial support from the Natural Sciences and Engineering Research Council of Canada is also gratefully acknowledged.

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