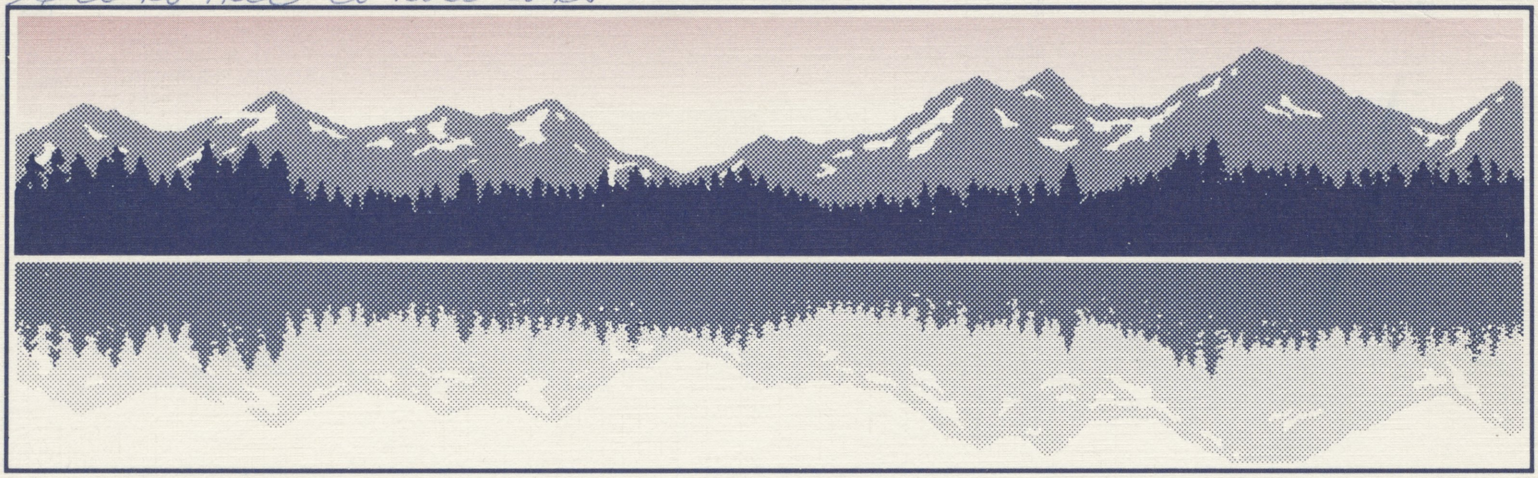
Economic conditions



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THE DEMAND FOR AND SUPPLY OF LABOR IN PACIFIC NORTHWEST SOFTWOOD LUMBER SAWMILLS, 1951-1985

by

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ABSTRACT

From 1951 to 1985, the amount of labor employed in Pacific Northwest softwood lumber mills decreased by more than 50% (from 72,000 to 34,000 FTE). About 90% of this decline occurred during the first 20 years of the period, i.e., 1951-1970. Sawmill owners reduced their labor requirements in response to a 63% increase in real wages. Sawmill production workers, meanwhile, were attracted to a 73% increase in real wages in other sectors of the economy. During the 1971-1985 period, however, sawmill production workers faced cuts in real wages both in the lumber industry as well as in other sectors of the economy. Sawmill owners cut back both wages and employment during this period because of a 23% fall in the price of softwood lumber. Two other variables also contributed to the 1971-1985 decrease in the region's sawmill employment — the decline in the region's private sawtimber inventories and the rise in the real interest rate.

INTRODUCTION

From 1951 to 1985, the amount of labor employed in Pacific Northwest softwood lumber mills decreased by more than 50% — from 72,000 to 34,000 FTE. This decrease in employment has been reflected in the technological improvements in plant design, material handling equipment, and sawing machinery that have been introduced (D&H, 1977). In modern mills, lumber is processed by a smooth continuous flow that requires very little material handling. Where handling is still required, more reliance is placed on machinery. Greater use of large capacity log-loading tractors, for example, enable only one worker to move logs around and load them on the sawmill's infeed chain, where in the past many workers were required. These innovations, coupled with increased use of push button automatic controls, have enabled sawmills to raise production line speeds, while reducing the number of workers needed on the mill floor.

Labor, however, is not the only input that the Pacific Northwest's lumber industry has been trying to reduce during the 1951-1985 period. Lumber producers have adopted a number of technologies that have reduced the amount of sawlog per unit of output as well. The introduction of thinner saw blades, for example, increased lumber output from a given sized log by reducing the amount of wood converted to sawdust (Duke and Huffstutler D&H), 1977). Another major technological change involving sawlogs is the trend to manufacturing lumber from small logs (D&H, 1977; Williston, 1979). These changes have been driven by increasing stumpage costs caused by declines in the region's commercial stocks of virgin and old growth timber and increases in the demand for veneer logs and pulpwood. One would also expect that increases in stumpage costs, which translate into decreases in sawlog supply, might have indirectly reduced sawmill employment as well. The purpose of this paper is to determine how these and other factors influencing the region's softwood lumber industry have affected sawmill employment in the Pacific Northwest in the past.

METHODOLOGY

The first step in determining the impact that major factors have had on employment in the region's sawmills was to develop a general model of the softwood lumber industry in the Pacific Northwest. The second step was to derive a specific model of the region's lumber industry so that the major effects could be quantitatively estimated. The third step was to collect the data necessary to construct the set of variables specified in the model. The fourth step was to estimate the major effects.

The result of the first step, i.e., a general model of the softwood lumber industry in the Pacific Northwest, is presented in Table 1. The model consists of four pairs of demand and supply equations. One pair of equations pertains to the market the output (softwood lumber). Three pairs of equations pertain to the markets for inputs (sawlogs, labor, and sawmills).

The core of the model consists of the lumber supply function and the demand functions for each of the three inputs. These four equations have the same endogenously derived "independent" variables: the price of softwood lumber, the price of softwood sawlogs, wages paid to sawmill employees, and the cost of sawmills.[1] The first derivative of the price of softwood lumber is expected to be positive in all four equations. What this means is that as the price of lumber increases, lumber producers as a group produce more lumber and, therefore, require more inputs, all else held equal. The first derivatives of the input prices are expected to be negative in the lumber supply equation and in their respective input demand equations. What this means is that as the price of an input such as sawlogs increases, lumber producers as a group produce less lumber and use less sawlog as an input, all else equal. The other derivatives in the model's core are positive or negative depending on whether the inputs are substitutes or complements, respectively.

The lumber demand equation contains five independent variables: the price of softwood lumber produced in the Pacific Northwest, the price of Canadian softwood lumber, the price of softwood plywood, the real interest rate, and U.S. per capita income. The first derivative of the price of softwood lumber in the lumber demand equation is expected to be negative. People who use softwood lumber in their production processes will use less if the price of lumber increases. The first derivatives of Canadian lumber and plywood prices are expected to be positive, i.e., people will use more Pacific Northwest softwood lumber instead of Canadian lumber or softwood plywood, if the prices of these products rise. The first derivative of the real interest rate is expected to be negative, while the first derivative of per capita income is expected to be positive. A major component of the demand for softwood lumber is the housing industry. Typically, if the real interest rate rises, the demand for new houses (and lumber) decreases. If, on the other hand, per capita income rises, the demand for new houses (and lumber) increases.

The sawlog supply equation contains six independent variables: the price of softwood sawlogs (paid by lumber producers); the price of exported sawlogs; the price of pulpwood, chips, and residues; the price of veneer logs; the real interest rate; and the volume of softwood sawtimber inventory on private commercial forest land. The first derivative of the price of softwood sawlogs in the softwood sawlog supply equation is expected to be positive. If lumber producers increase the amount they are willing to pay for softwood sawlogs, then sawlog producers will provide more sawlogs to lumber producers. The first derivative of the price of exported sawlogs is expected to be negative. If foreign buyers increase the amount they are willing to pay, the sawlog producers will sell more logs to foreign buyers and fewer logs to domestic lumber producers.

The first derivatives of pulpwood and veneer log prices are positive or negative depending on whether pulpwood and veneer logs are producer complements or substitutes, respectively. Some logs might be sold as either sawlogs or pulpwood. Other logs might be sold as either sawlogs or veneer logs. One would expect, therefore, that, if pulpwood or veneer log prices increased, then sawlog producers would provide fewer sawlogs to lumber producers, all else equal. All three kinds of logs, however, may be harvested jointly in today's clearcutting operations, and, in order to provide more of one kind of log, the logger might just as well provide more of the others as well.

The real interest rate is included in the sawlog supply equation to represent the discount rate, a factor that affects the optimum rotation. A rotation is the length of time between planting and harvesting trees. Usually, an increase in the discount rate is expected to shorten the optimum rotation (Howe, 1979). Shortening the optimum rotation, in turn, would mean an increase in the supply of logs. Howe also points out, however, that an increase in the discount rate might lengthen the optimum rotation. Also, even though we would usually expect the overall number of logs to increase, we do not know if the amount of sawlog would increase. The amount of sawlog harvested might actually decrease. Therefore, we can not tell a priori whether the first derivative on the real interest rate will be positive or negative. The first derivative on the inventory of softwood

1. Lagged prices are included in the sawmill demand equation to account for the greater stickiness associated with entering or exiting the industry relative to employing or not employing labor or sawlogs.

TABLE 1. System of General Equations Used to Model the Softwood Lumber Industry in the Pacific Northwest

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Softwood Lumber

Demand: $F(\mathbf{P},\mathbf{Q},\mathbf{X}) = DL(PL,PP,PF,R,Y) - QL = 0$

$F_{PL} < 0, F_{PP} > 0, F_{PF} > 0, F_{R} < 0, F_{Y} > 0$

Supply: $G(\mathbf{P},\mathbf{Q},\mathbf{X}) = SL(PL,PS,PN,PK) - QL = 0$

$G_{PL} > 0, G_{PS} < 0, G_{PN} < 0, G_{PK} < 0$

Equilibrium: $DL(\circ) = SL(\bullet) = QL$

Softwood Sawlogs

Demand: $H(\mathbf{P},\mathbf{Q},\mathbf{X}) = DS(PL,PS,PN,PK) - QS = 0$

$H_{PL} > 0, H_{PS} < 0, H_{PN} \gtrless 0, H_{PK} \gtrless 0$

Supply: $I(\mathbf{P},\mathbf{Q},\mathbf{X}) = SS(PS,PE,PC,PV,R,I) - QS = 0$

$I_{PS} > 0, I_{PE} < 0, I_{PC} \gtrless 0, I_{PV} \gtrless 0, I_{R} \gtrless 0, I_{I} > 0$

Equilibrium: $DS(\bullet) = SS(\bullet) = QS$

Softwood Sawmill Labor

Demand: $J(\mathbf{P},\mathbf{Q},\mathbf{X}) = DN(PL,PS,PN,PK) - QN = 0$

$J_{PL} < 0, J_{PS} \gtrless 0, J_{PN} < 0, J_{PK} \quad 0$

Supply: $K(\mathbf{P},\mathbf{Q},\mathbf{X}) = SN(PN,PA) - QN = 0$

$K_{PN} > 0, K_{PA} < 0$

Equilibrium: $DN(\bullet) = SN(\bullet) = QN$

Softwood Sawmills

Demand: $L(\mathbf{P},\mathbf{Q},\mathbf{X}) = DK(PL,PS,PN,PK,PL1,PS1,PN1,PK1) - QK = 0$

$L_{PL} > 0, L_{PS} \gtrless 0, L_{PN} \gtrless 0, L_{PK} < 0$

$L_{PL1} > 0, L_{PS1} \gtrless 0, L_{PS1} \gtrless 0, L_{PK1} < 0$

Supply: $M(\mathbf{P},\mathbf{Q},\mathbf{X}) = SK(PK,R,PA) - QK = 0$

$M_{PK} > 0, M_{R} < 0, M_{PA} < 0$

Equilibrium: $DK(\bullet) = SK(\bullet) = QK$

TABLE 1. System of General Equations Used to Model the Softwood Lumber Industry in the Pacific Northwest

(Continued)

Notation

P is a vector of the endogenous prices in the system. The vector consists of the prices for softwood lumber (PL), softwood sawlogs (PS), softwood sawmill labor (PN), and softwood sawmills (PK).

Q is a vector of the endogenous quantities in the system. The vector consists of numerical measures for softwood lumber (QL), softwood sawlogs (QS), softwood sawmill labor (QN), and softwood sawmills (QK).

X is a vector of the exogenous and predetermined variables in the system. The exogenous variables include the price of softwood plywood (PP), the price of foreign softwood lumber (PF), the potential return on an alternative investment (R), per capita income (Y), the price of exported sawlogs (PE), the price of pulpwood, chips, and residues (PC), the price of softwood veneer logs (PV), private softwood timber inventory (I), and the average wage for non-agricultural employment (PA). The predetermined variables include the previous year's prices for softwood lumber (PL1), softwood sawlogs (PS1), softwood sawmill labor (PN1), and softwood sawmills (PK1).

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sawtimber on private commercial timberland is expected to be positive. If the inventory of sawtimber increases, stumpage prices will decrease and sawlog producers will provide more sawlogs, all else equal.

The sawmill labor supply equation contains two independent variables: the wage paid to sawmill employees, and the average wage paid to industrial employees generally. The first derivative of the wage paid to sawmill employees is expected to be positive in the sawmill labor supply equation. All else equal, people will offer to work in sawmills more if the wage paid for working in sawmills increases. The first derivative of the wage paid to industrial employees generally is expected to be negative. The wage paid to industrial employees generally represents the alternative wage for prospective sawmill employees. If the average wage paid to industrial employees increases, then people will offer to work in sawmills less and in other sectors of the economy more.

The sawmill supply equation contains three independent variables: the cost of sawmills, the real interest rate, and the average wage paid to industrial employees. The first derivative of the cost of sawmills is expected to be positive in the sawmill supply equation. If the costs of sawmills increases, the number of sawmills that sawmill producers will provide will increase. The first derivatives on the real interest rate and the average wage for industrial employees are expected to be negative. These variable represent the costs associated with producing a sawmill and, all else equal, if one of these variables increases, then the number of sawmills provided will decrease.

The second step, i.e., deriving a specific model of the region's lumber industry, was implemented by selecting functional forms for the equations and by formulating a set of dummy variable to account for technological and other changes. In this research, Generalized Leontief (GL) profit functions provide the framework for estimating Marshallian output supply and input demand responses. Demand and supply equations are obtained by differentiating the profit function with respect to output and input prices.

DARWIN

The general formulation of the GL profit function is:

$$p = \sum_{i=1}^{n} \sum_{j=1}^{n} A_{ij} P_{ij}^{1/2} \quad (1)$$

where π is economic profit
n is the total number of input and output prices in the system
P represents the input and output prices in the system
A represents the parameters such that A_{ij} equals A_{ji}.

Differentiating $\pi(\bullet)$ with respect to output prices and setting the results equal to output quantities yields the following general formulation:

$$Q_s = \sum_{j=i}^{n} Aij \; P_i^{-1/2} P_j^{1/2} \quad (2)$$

where Q_s is the quantity of the output supplied.

Similarly, differentiating $\pi(\bullet)$ with respect to input prices and setting the results equal to the negative of input quantities yields the following general formulation:

$$Q_{di} = \sum_{j=1}^{n} A_{ij} \; P_i^{-1/2} P_j^{1/2} \quad (3)$$

where Q_{di} is the quantity of the input demanded.

As mentioned above, sawmill owners have introduced technological changes that have reduced the amount of labor and sawlog per unit of lumber output. Other changes have occurred as well. The trend to smaller logs, for example, has also generated a phenomenon that gives the appearance of technological change. The Scribner log rule (the standard sawtimber measure used in cost data) provides underestimates of lumber tally output from small diameter logs (Spelter, 1980; Adams and Haynes, 1980). This means that more lumber can be obtained from a small log than the rule would indicate. As the average sawlog diameter has declined in the Pacific Northwest over time, the size of the underestimation has grown. giving the appearance that more board feet of lumber are being obtained from a given quantity of sawlog than is actually the case.

Another change that had a major impact on the lumber industry was the implementation of more liberal lumber size standards in the early 1970s (Spelter 1980). Lumber size standards were last revised in 1970. The revised standard permitted 11% less wood in a board foot of dressed, dried 2 x 4 than the prior standard. Volume gains similar to the above in other lumber sizes gave the appearance of a major short-term technological advance in milling technology.

On the other side of the market, industries that use lumber as an input have adopted lumber-reducing technologies. Advances in fastening methods, which led to the growth of the light wood truss industry during the late fifties, for example, had a major impact on the softwood lumber market (Spelter, 1985). The use of light wood trusses entails substantial savings in softwood lumber relative to conventional rafter and framing construction, and reduced the demand for softwood lumber generally.

The effects of the technological and other changes were incorporated into the models by using dummy variables. The introduction of the new lumber size standards in the early 1970s, for example, was estimated by a set of parameter shift variables. Unidirectional incremental changes, i.e., changes associated with technological advances or the reduction in average sawlog dimensions, were estimated with time varying parameters. Two sets of time-varying parameters were used — one to cover the period prior to the revision of the lumber size standards (1951-1970), and the other to cover the period after the revision (1971-1985). In essence, therefore, three dummy variables were assigned to each independent variable — a trend term for the 1951-1970 period, another trend term for the 1971-1985 period, as well as a shift dummy for the 1971-1985 period.

The underlying (and testable) assumption is that distinct models, each with a unique set of time-varying parameters, are appropriate for the different periods. Mathematically, the general formulation for such a model with one independent variable would be:

$$Y_{1t} = (B_1 + b_1T_1)X_{1t'} \quad t = (1,20); \quad T_1 = (1,35) \tag{4}$$

$$Y_{2t} = (B_2 + b_2T_2)X_{2t'} \quad t = (21,35); \quad T_2 = (21,35) \tag{5}$$

Combining Equations (X.1) and (X.2) yields the following system:

$$\begin{bmatrix} Y_{1t} \\ Y_{2t} \end{bmatrix} = B_1 \begin{bmatrix} X_{1t} \\ X_{2t} \end{bmatrix} + C \begin{bmatrix} 0 \\ X_{2t} \end{bmatrix} + b_1T_1 \begin{bmatrix} X_{1t} \\ X_{2t} \end{bmatrix} + C\ T_2 \begin{bmatrix} 0 \\ X_{2t} \end{bmatrix} \tag{6}$$

where $C = B_2 - B_1$ and $c = b_2 - b_1$.

These dummy variables are easily incorporated into a GL profit function:

$$p = \sum_{i=1}^{n} \sum_{j=1}^{n} B_{1ij} P_{ij}^{1/2} + \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij}TS\ P_{ij}^{1/2}$$

$$+ \sum_{i=1}^{n} \sum_{j=1}^{n} b_{1ij}T1\ P_{ij}^{1/2} + \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij}T2\ P_{ij}^{1/2} \tag{7}$$

where T1 represents the incremental change dummy variable for the 1951-1970 period, TS represents the new lumber size shifter variable, and T2 represents the incremental change variable for the 1971-1985 period.

The third step was to collect the data necessary to construct the set of variables specified in the model. The data used in this analysis were obtained from a variety of sources (see Ulrich, 1987; Adams, Jackson, and Haynes (AJ&H), 1987; U.S. Bureau of Labor Statistics (BLS); U.S. Council of Economic Advisors (CEA), 1986; U.S. Forest Service's Pacific Northwest Research Station (PNRS), 1979; Oregon's Department of Human Resources (ODHR); Washington's Employment Security Department (WESD); Warren, 1988; and the Western Wood Products Association (WWPA)).

In most cases, the data were aggregated or otherwise manipulated so as to obtain the variables desired. In some sources, for example, the data on the Pacific Northwest are presented according to an eastside-westside format (AJ&H, 1987). Employment data for the Pacific Northwest, on the other hand, were presented by each state's employment bureau only for its respective jurisdiction. Data from these sources were aggregated to obtain variables pertinent to the Pacific Northwest as a whole. Some data series contained missing values or the desired variable was combined with extraneous information. Ways to fill the missing observations or to isolate the required information were developed. Finally, the producer price index (1967 = 1.000) was used to convert nominal price and income data into constant dollars.[2]

Definitions of the variables, their units of measure, and sources are as follows:

I - Softwood timber inventory (million cubic feet) on private commercial timberland in the Pacific Northwest. Source: AJ&H, 1987.

PA - Average person-year earnings (constant dollars) for private non-agricultural employment. Source: CEA, 1986.

PC - Pulpwood, chip, and residue price (constant dollars per bone-dry ton) in the Pacific Northwest, Westside. Source: AJ&H, 1987.

PE - Value of softwood sawlogs (constant dollars per thousand board feet) exported from Washington and Oregon ports. Source: PNRS, 1979 and Warren, 1988.

PF - Price of Canadian softwood lumber (constant U.S. dollars per thousand board feet, lumber tally, f.o.b. mill) in Canada. Source: AJ&H, 1987.

PK - Average annual capital cost (constant dollars) per softwood lumber mill in the Pacific Northwest. Source: AJ&H, 1987; WWPA; ODHR; and WESD.

PL - Softwood lumber price (constant dollars per million board feet, lumber tally, f.o.b. mill) in the Pacific Northwest. Source: AJ&H, 1987.

PN - Average person-year wage (constant dollars) of production workers in softwood sawmills in the Pacific Northwest. Source: BLS, ODHR, and WESD.

PP - Softwood plywood price (constant dollars per thousand square feet, 3/8 inch basis) on the west coast. Source: AJ&H, 1987.

PS - Softwood sawlog price (constant dollars per million board feet, Scribner log scale, c.i.f.) in the Pacific Northwest. Source: AJ&H, 1987.

PV - Douglas-fir veneer log (grade number 3) prices (constant dollars per thousand board feet, Scribner log scale) in the Pacific Northwest Westside. Source: Ulrich, 1987.

QK - Number of active softwood lumber mills in the Pacific Northwest. Source: WWPA.

QL - Softwood lumber production (million board feet, lumber tally) in the Pacific Northwest. Source: AJ&H, 1987.

QN - Annual employment (2000-hour-person-years) of production workers in softwood sawmills in the Pacific Northwest. Source: BLS, ODHR and WESD.

QS - Softwood sawlogs (million board feet, Scribner log scale) used in lumber production in the Pacific Northwest. Source: AJ&H, 1987.

R - Gross real returns on three-month U.S. Treasury bills. Source: CEA, 1986.

Y - Annual per capita income (constant dollars) in the United States. Source: CEA, 1986.

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2. For a copy of the data, along with a description of how the data were used to create the variables, send a self-addressed, 9 x 12 manila envelope to the R. F. Darwin, K6-57; Battelle - Pacific Northwest Laboratory; P.O. Box 999; Richland, Washington 99352.

The fourth step was to estimate the results. Parameter estimates of the demand and supply equations in the model were obtained econometrically using both ordinary least squares (OLS) and two-stage least squares (2SLS). Before the 2SLS methodology could be used, however, each equation was linearized by multiplying each equation by the square root of the price with the negative exponent. The linearized equations are presented in Table 2. The core equations in the model, i.e., the lumber supply and sawlog, sawmill labor, and

TABLE 2. Linearized Forms of Equations Used to Obtain Estimates of Important Parameters in the Pacific Northwest's Softwood Lumber Industry

Softwood Lumber

Demand: $PL^{1/2}QL = \gamma_{11}PL^{1/2} + \beta_{11}PP^{1/2} + \beta_{12}PF^{1/2} + \beta_{13}R1/2 + \beta^{1/2}_{14}Y$

Supply: $PL^{1/2}QL = \alpha_{11}PL^{1/2} + \alpha_{12}PS^{1/2} + \alpha_{13}PN^{1/2} + \alpha_{14}PK^{1/2}$

Softwood Sawlogs

Demand: $PS1/2QS = \alpha_{21}PL^{1/2} + \alpha_{22}PS^{1/2} + \alpha_{23}PN^{1/2} + \alpha_{24}PK^{1/2}$

Supply: $PS^{1/2}QS = \gamma_{22}PS^{1/2} + \beta_{24}PE^{1/2} + \beta_{25}PC^{1/2} + \beta_{26}PV^{1/2} + \beta_{27}R^{1/2} + \beta_{28}I^{1/2}$

Softwood Sawmill Labor

Demand: $PN^{1/2}QN = \alpha_{31}PL^{1/2} + \alpha_{32}PS^{1/2} + \alpha_{33}PN^{1/2} + \alpha_{34}PK^{1/2}$

Supply: $PN^{1/2}QN = \gamma_{33}PN^{1/2} + \beta_{38}PA^{1/2}$

Softwood Sawmills

Demand: $$PK^{1/2}QK = \alpha_{41}PL^{1/2} + \alpha_{42}PS^{1/2} + \alpha_{43}PN^{1/2} + \alpha_{44}PK1/2 + \phi_{41}PL^{1/2}_{-1} + \phi_{42}PS^{1/2}_{-1} + \phi_{43}PN^{1/2}_{-1} + \phi_{44}PK^{1/2}_{-1}$$

Supply: $PK^{1/2}QK = \gamma_{44}PK^{1/2} + \beta_{46}PA^{1/2} + \beta_{48}R^{1/2}$

sawmill demand equations, were estimated with all symmetry conditions imposed. F-statistics were calculated from the OLS models and used to determine whether distinct models, each with a unique set of time-varying parameters, are appropriate for the core equations during the two periods, i.e., 1951-1970 and 1971-1985. The tests indicated that distinct models are appropriate for each of the periods.

After the parameters of the model were estimated, first derivatives of all the variables in all equations were calculated for the 1971-1985 period. These first derivatives were then used in a comparative statics analysis to estimate the per-unit impacts of variables that are only indirectly associated with sawmill employment such as Canadian lumber prices or per capita income. The per-unit impacts were combined with the total net changes in these variables over the period to provide rough estimates of the total net impacts.

RESULTS

First partial derivatives of the sawmill labor demand equation are presented in Table 3. The derivatives of the softwood lumber price and the sawmill labor wage are statistically significant at the 0.1% level during both periods. The demand for sawmill labor is relatively inelastic with respect to both sawmill labor wages and the price of softwood lumber. In the 1951-1970 period these elasticities are approximately equal to 0.80. In the 1971-1985 period these elasticities drop to about 0.70. The first derivatives of the softwood sawlog price and sawmill costs are not statistically different from zero. The inputs, therefore, are gross unrelated.

TABLE 3. The Demand for Sawmill Labor in the Pacific Northwest

(First Partial Derivatives Estimated at Period Means)

Variable	Period 1951-1970	Period 1971-1985
Softwood Lumber Price	0.489*	0.310*
Softwood Sawlog Price	-0.137	-0.034
Sawmill Labor Wage	-7.411*	-4.150*
Sawmill Costs	0.067	0.006

* Statistically significant at the 0.1% level

First partial derivatives of the sawmill labor supply equation are presented in Table 4. The derivatives of both the sawmill labor and alternative wages are statistically significant at the 1.0% level during the 1951-1970 period. The supply of sawmill labor is relatively elastic with respect to both sawmill labor and alternative wages, i.e., about 1.43. The first derivatives of the sawmill labor and alternative wages during the 1971-1985 period are not statistically different from zero.

These results can be used to explain some of the changes in sawmill employment that have occurred over the 1951-1985 period. From 1951 to 1985, the amount of labor employed in Pacific Northwest softwood lumber mills decreased by more than 50% (from 72,000 to 34,000 FTE). About 90% of this decline occurred during the first 20 years of the period, i.e., 1951-1970. During this period wages in both sawmills and in the economy as a whole steadily and substantially increased (63 and 73%, respectively). The price of lumber, on the other hand, declined somewhat (about 8%). Sawmill owners, therefore, reduced their labor requirements. Sawmill production workers, meanwhile, were attracted to increases in real wages in other sectors of the economy.

During the 1971-1985 period, however, softwood lumber prices fell 23%, while wages in other sectors of the economy fell by about 8%. Sawmill owners, therefore, were able to cut back both wages and employment, and sawmill production workers were faced with cuts in real wages both in the lumber industry as well as in other

TABLE 4. The Supply of Sawmill Labor in the Pacific Northwest

(First Partial Derivatives Estimated at Period Means)

Variable	Period 1951-1970	Period 1971-1985
Sawmill Labor Wage	13.179*	1.136
Alternative Wage	-16.029*	-1.490

* Statistically significant at the 1.0% level.

sectors of the economy. Other variables affected sawmill employment in the region during the 1971-1985 period, too. Variables with positive net impacts are presented in Table 5. Variables with negative net impacts are presented in Table 6.[3]

The major positive impacts included a net increase in the price of veneer logs as well as a net increase in per capita income. The major negative impacts included a net increase in the real interest rate and a net decrease in private sawtimber inventories. Of particular interest was the impact of the price of exported sawlogs. As expected, increases in the price of exported sawlogs cause a reduction in the supply of sawlogs to domestic sawmills. Eventually this reduction causes sawmill employment to decrease. During the 1971-1985 period, however, the price of exported sawlogs fell slightly, so sawmill employment was beneficially affected. This is, however, only one way that the export of sawlogs affects sawmill employment. Sawlog exports also have an impact on private sawtimber inventories. All else equal, private sawtimber inventories decrease as the quantity of sawlogs exported increases. This process requires further investigation.

TABLE 5. Positive Net Impacts on Sawmill Employment, 1971-1985
(Change in Person-Years)

Variable	Per unit Impacts	Net Impacts
Price of Exported Sawlogs	-18.721	124.12
Pulpwood Price	-30.995	189.07
Veneer Log Price	11.063	605.15
Per Capita Income	0.889	670.30

3. The magnitude of the net impacts presented in this paper are at best rough approximations. The dynamics of the models used to obtain the impacts have not been taken into account as yet. Until the dynamics are more fully investigated only the relative magnitude of the impacts are likely to be of value.

TABLE 6. Negative Net Impacts on Sawmill Employment, 1971-1985
(Change in Person-Years)

Variable	Per unit Impacts	Net Impacts
Plywood Price	14.280	-100.83
Canadian Lumber Price	19.081	-342.89
Real Interest Rate	-127.833	-865.43
Private Sawtimber Inventories	0.212	-1,606.54

REFERENCES

Adams, D. M. and R. W. Haynes. 1980. *The 1980 Softwood Timber Assessment Market Model: Structure, Projections, and Policy Simulations. Forest Science*, Monograph 22. Supplement to *Forest Science* 26(3). 64 pp.

Adams, D. M., K. C. Jackson, and R. M. Haynes (AJ&H). 1987. *Production, Consumption, and Prices of Softwood Products in North America: Regional Time Series Data, 1950-85*. Resource Bulletin PNW-RB- , U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Howe, C. W. 1979. *Natural Resource Economics*. John Wiley & Sons, Inc., New York, New York.

Duke, J. and C. Huffstutler. 1977. "Productivity in sawmills increases as labor input declines substantially." *Monthly Labor Review* 100(4):33-37.

Oregon. Department of Human Resources. Employment Division. Research and Statistics (ODHR). *Average Weekly Earnings, Average Weekly Hours, and Average Hourly Earnings of Oregon Workers in Selected Industries*. Annual sheets, 1950-1985, Salem, Oregon.

Oregon. Department of Human Resources. Employment Division. Research and Statistics (ODHR). *Oregon Nonagricultural Wage and Salary Employment*. Annual sheets, 1970-1985, Salem, Oregon.

Oregon. Department of Human Resources. Employment Division. Research and Statistics (ODHR). *Labor Force and Employment in Oregon*. Annual sheets, 1950-1969, Salem, Oregon.

Spelter, H. 1980. "Trends in softwood sawmill overruns and their impact on stumpage prices." *Forest Products Journal* 30(9):21-24.

Spelter, H. 1985. "A product diffusion approach to modeling softwood lumber demand." *Forest Science* 31(3):685-700.

Ulrich, A. H. 1987. *U.S. Timber Production, Trade, Consumption, and Price Statistics 1950-85*. Miscellaneous Publication No. 1453, U.S. Department of Agriculture, Forest Service, Washington, D.C.

U.S. Council of Economic Advisors (CEA). 1986. *Economic Report of the President: Transmitted to the Congress February 1986*. Government Printing Office, Washington, D.C.

U.S. Department of Agriculture. Forest Service. Pacific Northwest Research Station (PNRS). 1979. *Production, Prices, Employment, and Trade in Northwest Forest Industries, First Quarter 1979*. (Resource Bulletin PNW-RB-). Portland, Oregon.

U.S. Department of Labor. Bureau of Labor Statistics. Division of Manpower and Employment Statistics (BLS). *Report on Hours and Earnings: Washington.* Annual sheets, 1950-1985, Washington, D.C.

U.S. Department of Labor. Bureau of Labor Statistics. Division of Manpower and Employment Statistics (BLS). *Total Nonagricultural Employment: Washington.* Annual sheets, 1950-1971, Washington, D.C.

Warren, Debra D. 1988. *Production, Prices, Employment, and Trade in Northwest Forest Industries, First Quarter 1988.* (Resource Bulletin PNW-RB-159). U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Washington. Employment Security Department. Research and Statistics Branch (WESD). *Nonagricultural Wage and Salary Workers Employed in Washington State.* Annual sheets, 1972-1985, Olympia, Washington.

Williston, E. 1979. "Lumber Manufacture: State-of-the-Art Report." *Forest Products Journal* 29(10):45-49.