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by

Peter Berck

RATIONAL EXPECTATIONS AND BIOLOGICAL FEASIBILITY IN THE PROJECTION OF SUPPLY AND DEMAND FOR DOUGLAS FIR STUMPAGE

Peter Berck*

I. Introduction

All current projections of the supply and demand for timber suffer from being either uneconomic (supply and demand are not balanced) or infeasible (projected supply exceeds the physical productive capacity of the biological system). This study presents long-range projections of prices and quantities of Douglas fir stumpage that suffer from neither defect. Previous projections of stumpage or lumber can be classified as either econometric or judgmental; both are either uneconomic or infeasible.

The U. S. Forest Service (1977) uses a judgmental approach; it projects demand from estimates of population including the population's housing and other timber-intensive "needs"; supply is estimated from net forest growth. The resultant prediction is that 16.6 billion board feet more lumber will be demanded than will be supplied in the year 2000. Since this projection is economically untenable, the U. S. Forest Service also produced a projection of the supply-demand situation if relative prices were to rise at about 1% per year and the elasticity of demand for timber were about .5; with rising relative prices, there would be a surplus of timber in the amount of 6.7 billion board feet in the year 2000. The surplus, though more comforting than the deficit, similarly defies the economic rule that prices clear markets; moreover, there is no guarantee that the private sector, which supplies a majority of the forest products, would supply them in the time profile in which they were demanded at the prescribed prices. If prices rise too slowly, all the supply is in the present period and occurs again in some faraway period. Prices rising too quickly cause entrepreneurs to hold the resource off the market. Judgmental forecasts, such as those of the U. S. Forest Service, can be said to be uneconomic because they do not have the property of materials balance; judgmental forecasts do meet the biological constraints of growing timber and are, therefore, feasible.

Although previous econometric estimates of the supply of stumpage have produced projections that track the short run passably well, the econometric equations imply that more stumpage will be produced yearly than is biologically possible; and they also imply a price path which would render the timber owners' projected supply decisions suboptimal. Robinson (1974) presents a linear stumpage supply equation for Douglas fir. The equation implies that, with prices and interest rates at their 1960 values, the producers could harvest in excess of 10 billion board feet of Douglas fir stumpage forever (or roughly 15 billion board feet of stumpage at five times the 1960's price). These numbers far exceed any sustainable yield. Adams (1975) estimates stumpage supply by regressing the ratio of output to the stock of timber squared on price and a constant. Again, the equation states that the forest can produce an arbitrarily large amount of stumpage per year; again, the biological constraints on how fast timber grows may be violated. Neither of these studies relates its projections of price to entrepreneurs' maximizing decisions. Adams predicts a rate of increase for stumpage price in the western coastal region of about 4.5% but predicts that, after the 1980's, stumpage prices will actually decline in the Western Pine region. While the projections for the West Coast are possible, those for the Western Pine region would induce timber owners in that region to cut all of their older growth before the 1980's price crash. The expectations about future prices generated by Adams' model are not consistent with the model's private harvest predictions.

The model used here to examine the Douglas fir stumpage market is both economic and feasible. It is characterized by rational expectations on the part of forest owners. Private owners are assumed to try to maximize the present value of their profits, given a set of expected prices. The expected prices are prices which each producer believes will balance supply and demand almost forever.[1] Section II describes the time period of the model, the relation of expected profits to supply, and the formation of price expectations. Section III describes the estimation of the demand equations. Section IV describes the producer's profit functions which are built from a linear model of biological growth of Douglas fir; this linear model assures that the projections of this paper are biologically feasible. Section V presents the estimation of the supply equation and the model's projections of quantity and price.

II. The Model: Price Expectations

Expected prices must clear markets. In each year (t), markets are envisioned for the six succeeding quarter centuries indexed by the letter j. $Q_j^t(P)$ is the demand equation expected in year t to prevail for the period ending in the year $t + 25 \cdot j$. Foresters are assumed to maximize the present discounted value of their profits, V^t, given the prices they expect, P^e, and a behavioral parameter r, the rate at which they discount future earnings. Expected prices are those which satisfy the equations that demand equals supply.

For every t from 1950 to 1970,

$$S_j^t\ (P^e,\ \bar{r}) = Q_j^t\ (P^e) \qquad \text{for } j = 1,\ 7, \tag{1}$$

where S is the supply functional and the indexing scheme is as above.

The market-clearing equations can be reexpressed in terms of the profit function by using Shepard's lemma,

$$D_{P_j}\ V^t\ (P^e,\ \bar{r}) = Q_j^t\ (P^e) \qquad \text{for } j = 1,\ 7, \tag{2}$$

where $D_{P_j}\ V^t$ is the partial derivative of V with respect to P_j and P^e is implicitly defined in equation (2).[2] $S^t\ (P^e,\ r)$ is a nonlinear function of the interest rate (its sole estimated parameter), the data (the endowment of Douglas fir), and the past records of demand which are summarized in the estimated demand equation Q. The behavioral parameter is then estimated by nonlinear least squares in the following way. A value of r is chosen (r^*). For each starting date (t) from 1950 to 1970, the seven equations (1) or (2) are simultaneously solved for the vector P^e.[3] Producers supply $1/25 \cdot D_{P_1}\ V^t\ (P^e,\ r^*)$ in year t. These predicted supplies are compared with the actual amounts supplied. For each r^*, the sum of squared residuals is computed; and $\bar{r}$ is that discount rate which minimizes the sum of the squared residuals.

III. Demand for Douglas Fir Stumpage

Douglas fir stumpage is logged, milled into either plywood or lumber, and used for construction and home furnishings. Minor amounts of stumpage (12% by Outlook estimates) are wasted (U. S. Forest Service, 1974), and minor amounts have other end uses. By far, the largest use is construction with 72% of lumber and 50% of plywood (Stanford Research Institute, 1954). It follows that the demand for stumpage should depend on the output of contract construction and home furnishings and the prices of the other goods used in producing this output. Both prices of competing materials and quantity of output present severe measurement problems as Gordon (1968) recognized.[4] The Federal Highway Administration, formerly the Bureau of Public Roads (BPR), provides an index of its purchase prices for three structural inputs--reinforcing steel, structural steel, and structural concrete--and uses these input prices to construct its own structures index (U. S. Federal Highway Administration, quarterly issues). The BPR structures index, though criticized by Gordon, is, in fact, quite close to Gordon's own index for the post-World War II period. Since Gordon's (1968) index ends at 1966, the BPR index is used here as the next most appropriate deflator for structures. The price of Douglas fir stumpage is the bid price in national forests and is taken from The Demand and Price Situation for Forest Products (U. S. Forest Service, annual issues). The quantity of stumpage traded is represented by removals constructed from the stumpage requirements of produced lumber and plywood with allowance for waste.[5]

The actual form chosen for the demand equation was to express the output of stumpage and the sum of deflated Value of Home Furnishings and deflated Value of New Construction as logarithms, while the other variables were expressed as the logarithms of a four-year moving average. The moving average form was chosen because structures are planned well in advance of the materials being ordered. The length of the lag was chosen experimentally. The equation is

$$\ln (\text{Remo}) = \alpha_0 + \alpha_1 \ln (\text{QFU}) + \alpha_2 \ln [\text{4YRM (PDFS)}] + \alpha_3 \ln [\text{4YRM (PSC)}]$$

$$+ \alpha_4 \ln [\text{4YRM (PST)}] + \alpha_5 \ln [(\text{4YRM (FAB)}] + \text{DWAR}$$

where ln is natural logarithm and 4YRM is a four-year moving average. The variables are defined in table 1.

TABLE 1

Variables

REMO	Douglas Fir Timber Removed (pieced together from Current Industrial Reports, Series M24H and M24T, and Outlook; 1,000 board feet international 1/4-inch rule).
PDFS	Price of Douglas Fir Stumpage (from The Demand and Price Situation for Forest Products; in dollars per 1,000 board feet international 1/4-inch rule).
PSC	Price Index of Structural Concrete (from Federal Aid Highway Index).
PST	Price Index of Structural Steel (from Federal Aid Highway Index).
FAB	Sum of the WPI for wallboard and structural paper.
DWAR	A dummy variable equal to 1 before 1943; 0 otherwise.
QFU	Sum of the Value of New Construction put in place, statistical abstract deflated by the Federal Aid Highway Structures deflator, and the Value of Home Furnishings from Historical Statistics of the U. S. and Statistical Abstract deflated by the GNP deflator for furniture and household durables.
C	Constant term.
SPINE	Price of Southern Pine stumpage (from Outlook; in dollars per 1,000 board feet international 1/4-inch rule).

A dummy variable was included to account for the differences between the pre- and postwar markets for timber. The widespread use of plywood and the availability of fabricated products are expected to have shifted the demand for timber in the postwar period.

The estimator used was two-stage least squares (2SLS). The instruments, in addition to the included exogenous variables, were the lagged stumpage prices and the stock of timber. The stock of timber is known with some precision only for 1972; earlier stocks were calculated by subtracting removals and adding growth. Unfortunately, removals, being the dependent variable, are certainly correlated with the error term. Under these circumstances, 2SLS may not be consistent. Ordinary least-squares (OLS) estimates were also prepared, and the two sets of estimates are quite close (differing at most by 6%). Table 1 presents the variable definitions; table 2, the 2SLS estimates for the entire period; and table 3, the OLS estimates for the entire period.

The results of the estimation are most remarkable for the small own-price elasticity; it is about -0.6. McKillop (1967), in his study of lumber demand, found the own-price elasticity for softwood lumber to be about 3, while he found a very low elasticity (.1) for plywood demand. Since Douglas fir goes to both of these products, an elasticity in between is quite plausible. The low elasticity is also supported by the high percentage of Douglas fir lumber used for construction, an industry which appears less flexible than most in its choice of techniques.

The magnitude of the output elasticity is quite reasonable. If stumpage were used only for new construction and furnishings, the deflators were ideal, and the aggregate cost function for construction and furnishings had constant costs, then the elasticity of demand with respect to QFU should be unity. The point estimate is 0.76.

TABLE 2

Instrumental Estimates, 1929-1942 and 1947-1972

Dependent Variable: REMO

Right-hand variable	Estimated coefficient	Standard error	t statistic
C	14.522	1.077	13.476
DWAR	- .569	.165	- 3.439
FAB	.033	.016	2.043
PSC	- 1.388	.389	- 3.564
PST	1.389	.334	4.158
QFU	.763	.081	9.393
PDFS	- .616	.110	- 5.572

R^2 statistic = .95; Durbin-Watson statistic = 1.9.

TABLE 3

Ordinary Least Squares, 1929-1942 and 1947-1955

Dependent Variable: REMO

Right-hand variable	Estimated coefficient	Standard error	t statistic
C	14.684	1.044	14.066
DWAR	- .568	.165	- 3.437
FAB	.033	.016	2.038
PSC	- 1.338	.389	- 3.570
PST	1.352	.328	4.118
QFU	.763	.081	9.408
PDFS	- .589	.101	- 5.796

R^2 statistic = .95; Durbin-Watson statistic = 1.9.

Steel and fabricated materials appear as substitutes, which is reasonable; and concrete appears as a complement, which is possible. Other substitutes for Douglas fir should include other varieties of lumber. But when the price of Southern Pine is included, it is not found to be significant [t(32) = 0.15]; and it does not change the other point estimates in the equation.[6] The regression used for this t test is shown in table 4.

The procedure for estimating the supply of stumpage calls for estimates of the demand equation, $Q^t(P)$, at yearly intervals because entrepreneurs making decisions in 1955, for example, had no knowledge of future (e.g., 1972) prices and conditions. Equations for the periods ending in 1955 and 1960 were estimated. Although the point estimates of the elasticities of demand for 1955 showed a small decrease from the 1972 estimates, an F test was used to show that the coefficient vector did not change significantly during either the 1955 or 1960 subperiods.[7] No statistically significant change was found in either subperiod, and the 1972 equation has been used as a representation of the demand equation believed by entrepreneurs to have existed for the whole period.

The fitted equations are used for predicting future demand. In these predictions it is assumed that the independent variables increase at an exponential rate determined by regressing the logarithm of each independent variable on a constant and the logarithm of a trend. Table 5 presents these regression results, and table 6 presents the projections of future demand equations.

IV. Producers' Profit and Supply Functions

Douglas fir stumpage is supplied by the private sector and the government. The government uses an administrative rule to decide its market supply, while the private sector is assumed to choose its supplies to maximize the present value of its profits subject to a biological production function and the sector's initial endowment of timberlands.

TABLE 4

Instrumental Estimates, 1929-1942 and 1947-1972

Dependent Variable: REMO

Right-hand variable	Estimated coefficient	Standard error	t statistic
C	14.448	1.244	11.611
DWAR	- .564	.171	- 3.286
FAB	.032	.017	1.804
PSC	- 1.360	.435	- 3.124
PST	1.349	.414	3.258
QFU	.760	.084	8.943
PDFS	- .608	.117	- 5.189
SPINE	.010	.066	.151

R^2 statistic = .95; Durbin-Watson statistic = 1.9.

TABLE 5

Regression of Exogenous Variables on a Trend
Log Linear Form

Variable	C	Trend	R_A^2
FAB	5.69 (.188)	.504 (.051)	.7998
PST	2.38 (.24)	1.14 (.07)	.87
PSC	2.89 (.22)	1.02 (.06)	.86
QFU	.839 (.23)	.99 (.07)	.84

TABLE 6

Projections of Demand Equations
Sample Values

$$REMO = B \times 10^{9} \times PDFS^{-.616}$$

Year	B
1950	.0580
1960	.0762
1970	.0943
1980	.1121
2000	.1474
2050	.2340
2100	.3189

Private Sector

The private sector's supply is governed by the entrepreneur's decision to hold or to sell the stumpage on individual acres of land. Should an entrepreneur decide to hold a parcel of land for an additional period (25 years), the owner will realize a gain from the growth of the timber and a loss from the taxes and management expenses involved in holding timberlands. Should the owner decide to sell the stumpage on an acre, the owner receives a cash payment for the timber and is left with the denuded land.

As before, let t refer to a base year in which the strategy is formulated, j to the current period, i to the age class, and s to the site class.[8] X (t, j, i, s) is the number of acres of site class s trees that are 25 • i years old at time t + 25 • j. The value of those acres is λ (t, j, i, s). The value of the stumpage on land of age class i and site class s at time t + 25 • j is the number of board feet per acre, RM (i, s), times the price of stumpage, P (t, j). This stumpage value must be discounted back to the base year t by dividing by $(1 + r)^{25 \cdot j}$. The cost of holding stumpage for another time period is denoted RE (t, j, i, s); and it too is discounted back to the base year. The sources for and further discussion of these variables are given in the Appendix.

The value of land with timber is determined recursively by choosing the option (hold or sell) that maximizes present value. Arbitrarily, it is assumed that in period 7 (i.e., after 150 years) all timber is cut.[9]

$$\lambda\ (t,\ 7,\ i,\ s) = P\ (t,\ 7) \cdot \frac{RM\ (i,\ s)}{(1 + r)^{7 \cdot 25}} .$$

For any other time period, the forest owner has the choice of holding or selling the stumpage. Holding the land makes it worth an amount Z (t, j, i) which is what 25-year older land would be worth in 25 years less the holding costs:

$$Z\ (t,\ j,\ i,\ s) = \lambda\ (t,\ j+1,\ i+1,\ s) - \frac{RE\ (t,\ j,\ i,\ s)}{(1+r)^{j \cdot 25}}.$$

When an owner elects to sell his stumpage, he receives a sum Y (t, j, i) which is the cash price of both the timber and the land that supports 25-year-old trees at the beginning of the next period. Thus,

$$Y\ (t,\ j,\ i,\ s) = \frac{P\ (t,\ j)}{(1+r)^{j \cdot 25}} \cdot RM\ (i,\ s) + \lambda\ (t,\ j+1,\ 1,\ s).$$

The policy that maximizes the present value of profits is to cut at least some timber if $Y \geq Z$ and save it otherwise.[10] The price of land with trees in period $j - 1$ is

$$\lambda\ (t,\ j-1,\ i-1,\ s) = \max\ [Z\ (t,\ j,\ i,\ s),\ Y\ (t,\ j,\ i,\ s)].$$

The value of an optimal program started at t when prices are P, the interest rate is r, and the initial endowment of timber, X (t, 0, i, s), is V (t, r, P, s).

$$V\ (t,\ r,\ P,\ s) = \sum_{i=1,7} \lambda\ (t,\ 0,\ i,\ s) \cdot X\ (t,\ 0,\ i,\ s)$$

which, when aggregated across site classes, becomes

$$V^t\ (r,\ P) = \sum_{s=1,3} V\ (t,\ r,\ P,\ s).$$

Public Supply

The public sector produces large amounts of stumpage and determines production according to an administratively set allowable cut. Public agencies calculate the maximum amount of lumber they can produce each year from a given tract of land (or, in U. S. Forest Service terminology, working circle or forest) and set that amount as an allowable cut. The calculation of allowable cut is not as scientific as it might at first seem. Old-growth forests have very little growth; if the object were to maintain them as old growth, the allowable cut would be very small indeed. Young forests have vigorous growth and would support large allowable cuts. The transition from old to young forest necessarily produces significant amounts of lumber, so any plan that contemplates a young forest in the long run must also contemplate cutting out the old growth. Cutting the old growth gives a production of lumber higher in the initial years than in the later years and also gives no old growth; public agencies are under considerable pressure from the public to maintain the old growth for recreational or sentimental reasons. The public agencies and particularly the U. S. Forest Service have set a noneconomic policy called allowable cut to deal with these problems of perceived public wants, timber production, and long-run supply.

Projections of public supply are available only for all softwoods in the Douglas fir region (Gedney, Oswald, and Fight, 1975). The percent of Douglas fir cut in the historic period (54%) was used to project the future supply of Douglas fir as a constant percentage of the future public supply of all softwood sawtimber in the Pacific Northwest. The assumption for the public sector is that the government will, in fact, produce its planned allowable cut at any price; however, this is not a very good assumption. The projections given by Gedney, Oswald, and Fight (1975) refer to a "lower level" of management. They also provide another projection--one for intensive management. It is hoped that, at least in the long run, price will determine whether or not the U. S. Forest Service undertakes a more intensive forest policy with its inherent expenses and increased public wood supplies.

V. Estimation of the Supply Function

Nonlinear least squares applied to $S^t(P^e, r)$ yields a point estimate of 4.5% for r. The 99.5% confidence interval for r was constructed using the fact that minus twice the logarithm of the likelihood ratio is asymptotically chi-squared. The confidence interval is (4.0%, 6.0%). The equation fit has an R^2 of .99 and an adjusted R_A^2 of -.5.[11] The interpretation is that the equation explains 99% of the variation of the timber output around zero while explaining none of the variation around a constant term. Simple timber-supply equations that use a constant and the timber stock (or a trend) in a linear equation will have an R_A^2 higher than this model's. The difference is that simple (or adaptive) expectations models explain the variation from some constant supply and not the constant itself. This study should be viewed as answering the question: Why do Douglas fir stumpage producers sell about 10 billion board feet per year rather than 5 or 20 billion board feet per year? Simple or adaptive studies accept the condition that about 10 billion is the right number and concentrate on explaining the variance (usually due to the business cycle) about the constant amount. When viewed in this light, the rational expectations model does a remarkable job of predicting the output of timber and of explaining what is the constant term in an adaptive or simple model.

The estimate of r is the return a forest owner believes he could get on an investment of similar risk. Forest ventures depending--as they do--on distant future demand are quite risky. For such a risky asset, 4.5% would seem low except that timber is accorded capital gains treatment. Since capital gains are taxed at half the rate of ordinary income, a return of 4.5% on an asset taxed at capital gains rates is more like a return of 7% at earned income rates; and 7% seems a good deal more reasonable.

The estimated equation indicates that entrepreneurs acting under the hypothesis of expectations rational with respect to both year-to-year fluctuations and the transversality condition and demanding a return of 4.5% would provide the market with the same quantitites of Douglas fir stumpage that were actually produced. An immediate corollary is that the entrepreneurs have cut timber in such a way that there will not be a timber famine--only a relentless increase in nominal prices.

Table 7 presents predictions of price, cut, and the ratio of stumpage price to structural steel price. Output declines from 9.24 billion board feet in 1970 to a sustained yield of 6 billion board feet in 2000. Prices advance first at 4% and then slow to 1.6%. The price ratio of stumpage and steel shows an even more striking decline in rate of increase: 2.3% to 1/2%. During the early part of the period (1970), old-growth timber was still in private hands. Entrepreneurs hold this timber off the immediate market only if the rate of price increase (4%) plus the rate of growth (.5%) equals the interest rate they use (4.5%). After 2000, the timber is "thrifty" young stands with a larger (2%) rate of growth. The rate of price increase (2.5%) plus the rate of growth again equals the estimated discount rate (4.5%).

Other implications are that, in the long run, the nominal price of timber would continue to increase and the amount of timber per housing unit would decrease. Renewable resources, such as Douglas fir stumpage, are sometimes viewed as being the salvation of an economy doomed by the exhaustion of its depletable resources. There exists a maximum sustainable yield (which is greater than the economically desirable yield) in the long run. If demand continues to grow, as is postulated here, then the fixed maximum amount of long-run output must be spread over more final product demand. The economic system handles this problem by making the resource more expensive and, thus, causing substitution away from both the final product and the resource in limited supply. All of these things happen in this model. If demand continues to grow at its historic rates and if there are no offsetting changes in technology, there would be an unhappy future.

TABLE 7

Projections of Stumpage Price, Relative Price, and Output

	Year			
	1970	1975	2020	2120
Projected price in dollars per thousands of board feet	49	123	223	570
Ratio of projected price to projected price of structural steel; index number	1	1.77	2.46	3.6
Stumpage output in billion board feet	9.24	7.08	6.52	6.32

APPENDIX

Sources of Data for Private Sector Stumpage

X (t, 0, i, s)

The acreage in year t of land of site class s with trees 25 • i years old. The Land Base for Management of Young-Growth Forests in the Douglas-Fir Region provides tables of acreage by type of owner, stand age, site class, and stocking (Fight and Gedney, 1973). Roughly, site class is a measure of the suitability of a site for growing timber, and stocking is the percent of the acre used for growing trees. This author aggregated these tables across stockings. The study assumes that the land base will be constant over the relevant period.

RM (i, s)

The number of board feet international 1/4-inch rule per acre of trees 25 • i years old on land of site class s. The Yield of Douglas-Fir in the Pacific Northwest (McArdle, Meyer, and Bruce, 1961) is a series of tables giving board feet volume as a function of stand age and site class.[a]

RE (t, j, i, s)

The cost of holding land of site class s with i year-old trees during the period ending in t + 25 • j. The data for the costs of growing timber and the taxes are taken from a report on forest taxation in Oregon and Washington (Palo Alto Research Association, 1970). Because many systems of forest taxation are used in the state of Oregon alone and each county applies a slightly different rate to the six methods of taxation, the costs and taxes represent a good deal of the author's judgment.[b] The costs of holding land of various age classes for 25 additional years in 1970 is on the order of $20 per acre for seedling and $700 per acre for old growth.

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[a] The yield tables were built from a short time series of a cross section of carefully selected sample plots. To qualify, a plot has to have a great preponderance of Douglas fir and be essentially even aged at the time of the sample. Plots that started as young-growth Douglas fir but encountered a catastrophe of sufficient magnitude to open the stand to younger growth or to destroy it completely--e.g., wind or tussock moths--are not included in the sample. When used for prediction, these tables have a clear upward bias.

[b] Increasing the costs and taxes slightly decreases the rotation ages, greatly reduces the profits to landowners, and only marginally affects the actual supplies of stumpage.

FOOTNOTES

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[1]The time horizon chosen is 150 years which is long enough so that the current period's supply is insensitive to a change in the end-time conditions.

[2]Where $D_{P_j} V$ exists; otherwise, $D_{P_j} V$ is the element of $\left(D^-_{P_j} V, D^+_{P_j} V\right)$ closest to Q^t.

[3]The functional,

$$F\,(P_1 \ldots P_7) = \left[\sum_{j=1,7} \int_{P_j}^{\infty} Q^t(z)dz\right] + V^t\,(p, r^*),$$

is minimized when equation (2) holds. Hotelling (1931) and Samuelson (1952) use similar devices.

[4]At the root of the price measurement problem is the reliance of the Wholesale Price Indexes on list prices which often differ substantially from the transaction or buyer's price. In most of the standard construction deflators, the effect of bad price data is much compounded by failure to account for quality and input mix changes. These problems are discussed at great length by Gordon (1967).

[5]Removals are not the same as stumpage sold because, in the national forests, the stumpage buyer has many seasons to remove the timber. Usually, removals and sales are of quite similar magnitude. Adams (1973) discusses the actual lags between cut and sold. Since the concern here is with a process that takes years, the difference between cut and sold seems of little importance.

[6]Since one expects a fair degree of substitutability among types of lumber and almost perfect substitutability among types of plywood, the low estimate of cross elasticity (.06) and the insignificance of that estimate for Southern Pine are puzzling. Two possible explanations are that (1) the transportation and transactions costs regionally separate the markets and (2) the data for Douglas fir come from national forest bids which are reasonably good, while those for Southern Pine prices are not similarly collected.

[7]The test was that of equality of all the coefficients in the periods ending in 1955 (especially 1960) and 1972. The critical value of $F_{.05}$ (7, 3) was 8.88; for 1955, F was .01, while for 1960 it was .069. The null hypothesis of constancy of the regression coefficients over the two subperiods is not rejected. For an explanation of the F test used, see Dhrymes (1974, p. 272).

[8]The study adds one further classification of land beyond the age of trees and time. Soils and climate make some sites more favorable for the growth of Douglas fir than others. The effects of these variables are summarized as a site class. Site classes differ in the amount of timber supported per acre at a given age.

[9]The results are not sensitive to this assumption.

[10]If $Z = y$, one cuts that fraction of standing timber which minimizes the distance between supply and demand.

[11]For an explanation of the use of R^2 and R_A^2, see Theil (1971).

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