Quality Adjusted Price Indices for Douglas-Fir Timber

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The purpose of this paper is to determine if there have been systematic changes in the characteristics of Douglas-fir stumpage sold on National Forests in the Pacific Northwest that would significantly bias the price of stumpage. Four hedonic methods were used to develop indices of pure price change holding stumpage characteristics constant. None indicated a significant trend in quality over the period 1968 to 1978. Quality differences, however, appeared to play a role in the year-to-year price changes. The advantages and inconveniences of each indexing method and their use for various purposes are discussed.

Unlike price statistics for manufactured forest products and many commodities, the price statistics for stumpage (standing timber) are not for a standardized commodity. For example, buyers of National Forest stumpage do not have the option of buying timber of a single species and quality. Instead, they must bid for an entire sale. But sales vary considerably in terms of species composition, density and volume of stands, timber quality, geographic location, and other characteristics that affect the value of the sale to the bidder. As a result, the reported prices for Douglas-fir stumpage sold from National Forests [Ruderman, Phelps][1] may reflect many factors besides its value.

The purpose of this research was to determine if there have been systematic changes in the characteristics of Douglas-fir stumpage sold on National Forests in the Pacific Northwest that would significantly bias the price of stumpage.

Four methods were used to develop indices of pure stumpage price changes holding stumpage characteristics constant. They consist in the adaptation of different "hedonic" multiple regression approaches to price indexing. All data came from National Forest sales in the Pacific Northwest from 1968 to 1978. No overall trend in quality was observed during that period. Quality differences, however, appeared to play a role in the year-to-year price changes. The advantages and inconveniences of each method and its potential practical use for various purposes will be discussed.

Methods

There are several ways of implementing

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[1]These are derived from the Forest Service "Report of Timber Sale" (2400-17) forms and represent the average price offered for Douglas-fir by the highest bidder for each sale.

the hedonic pricing approach, none of which has yet been shown to be optimal. In this study four of the most commonly used methods were applied and compared. The central assumption of the four methods used is that a timber sale is composed of a collection of characteristics, some yielding a stream of services, others a stream of costs to the buyer.[2] In his bid for Douglas-fir, the buyer places an implicit price, positive or negative, on each unit of all sale characteristics.

The implicit price of each characteristic is obtained by regression techniques using a cross-section sample of sales. Using these prices, the observed price of Douglas-fir timber is adjusted for variations in characteristics with respect to some reference sale.

This procedure was first suggested by Court to adjust automobile prices for quality changes. Other applications to automobile prices have followed [Adelman and Griliches; Griliches 1961, 1964, 1971; Cagan; Dhrymes 1967, 1971; Cowling and Cubbin]. The technique has been found particularly useful to adjust the price of residential housing for quality changes, as demonstrated in the works of Musgrave, Chinloy, Berry and Bednarz, Ferri, and Ridker and Henning. Of special interest for this study dealing with timber are the price indices developed by Gordon for capital goods.

Let P_i be the price per thousand board feet of Douglas-fir paid by the highest bidder on sale i. Based on the central assumption of hedonic pricing, one can write P_i as a function of a set of characteristics Q_1 to Q_k:

$$(1) \qquad P_i = f(Q_{1i}, \ldots, Q_{ki}, u_i) \qquad i = 1, \ldots, n_t$$

where u_i is a random term and n_t is the number of observations in a cross section of sales occurring in year t. The variables Q_1 to Q_k may be continuous (percentage of Douglas-fir timber in total volume sold, length of road) or dummy variables taking the value one if sale i falls in a particular category, for example if it occurs on a specific forest, zero otherwise.

The literature on stumpage price determination is extensive, and many studies give useful information about relevant quality characteristics. In an early empirical analysis of stumpage prices on private land in western Washington, Steer noted three variables which were among the most important determinants of the price paid. They were: distance from the mill, the density (volume per acre) of timber, and the percentage of cull loss and other substandard material. These variables explained less than 16 percent of the variation in stumpage price. Zivnuska and Schideler indicate that the characteristics which are likely to affect the price of a timber sale include species composition, tree or log grades, accessibility of the sale area, and stand density. Darr noted that unit prices tend to rise as the size of the timber sold increases but that the effect varies greatly across forests. Johnson found only two sale characteristics which were important in explaining stumpage prices, percentage of pulpwood and percentage of "per-acre-material" (PAM), the official Forest Service designation for cull loss and other substandard material. Both of these categories refer to low timber quality.

In choosing independent variables for equation (1), one must refrain from using variables which are not physical characteristics of a timber sale but, rather, the result of economic forces [Griliches, 1971]. This rules out, for example, the use of the lumber price index or the number of bidders as explanatory variables. Economic theory predicts that if lumber prices are high, timber sale prices will also be high, but this is a characteristic of the market environment in which the sale takes place, not a physical characteristic of the sale. In other words, the goal here is not to explain stumpage price changes but rather

[2]For a thorough discussion of the concept of a good as a bundle of characteristics, see Lancaster. However, Lancaster focuses on consumer goods. The characteristics of a timber sale are those of a capital good. Hedonic pricing of capital goods has been empirically studied by Gordon.

to provide a measure of these changes, net of variations in stumpage characteristics.

The form of the function in (1) is an empirical question (Palmquist, Halvorsen and Pollakowski). There is little reason to expect timber price and sale characterisitcs to be related in any specific fashion. A linear form will be used in this paper because of its simplicity and because it led to empirical results which were as plausible as those of other forms.[3]

Therefore, equation (1) can be written:

$$(2)\ P_i = a_o + a_1 Q_{1i} + \ldots + a_k Q_{ki} + u_i,\ i = 1, \ldots, n_t$$

where a_o to a_k are constant parameters.

Method I

An equation like (2) can be computed for each year for which there are enough observations. Generally, the results will not be the same in different years, and one is faced with the usual price index problem of changing weights. If this problem is ignored, the pure price change over a period t = 1, ... T is computed, as suggested by [Griliches 1961], by pooling all sales data over the entire period and adding a set of t − 1 time dummies to equation (2):

$$(3)\ P_i = a_o + a_1 Q_{1i} + \ldots + a_k Q_{ki} + b_2 Y_{2i} + \ldots + b_T Y_{Ti} + u_i \quad i = 1, \ldots, n_t \quad t = 1, \ldots, T$$

where

$Y_{ti} = 1$ iff i observation i falls in year t

$Y_{ti} = 0$ otherwise

In this equation, and in the rest of the paper, year 1 is the base year. As illustrated by Figure 1, each coefficient $\hat{b}_t$ provides an estimate of the change in price between year 1 (base year) and year t, holding the sale quality measured by the Q variables constant.

Let $\bar{P}_t$ be the average price of Douglas-fir in year t. Equation (3) indicates that if the base-year sales had been offered in year t, the average price of Douglas-fir on these same sales, $\hat{P}_t^1$, would have been:

$$(4)\quad \hat{P}_t^1 = \bar{P}_1 + \hat{b}_t,\ t = 2, \ldots, T.$$

Therefore, the pure price change between year 1 and t, PP_{1t}, is:

$$(5)\ PP_{1t} = \hat{P}_t^1 - \bar{P}_t,\ t = 2, \ldots, T,$$

and, since the unadjusted price change during the same interval, TP_{1t}, is:

$$(6)\ TP_{1t} = \bar{P}_t - \bar{P}_1 \quad t = 2, \ldots, T,$$

the change in price due solely to quality change, QP_{1t}, is:

$$(7)\quad QP_{1t} = TP_{1t} - PP_{1t} = \bar{P}_t - \hat{P}_t^1, \quad t = 2, \ldots, T.$$

One drawback of this method is that it imposes a common set of coefficients a_o to a_n over the entire period for which the index is computed. This means that the implicit price of a particular characteristic of a sale, say the size of timber, does not change over time, which may not be true. The assumption that the coefficients change over time will be tested formally.

Method II

The problem of changing weights can be dealt with using a chaining method of indexing [Griliches, 1961; Cowling and Cubbin]. This method uses a series of regression equations such as (3), each estimated for two adjacent years, with a single dummy variable, Y, to estimate the average price change over those two years, holding quality con-

[3]A Box-Cox transformation [Box and Cox, Zarembka], was used to examine alternative functional forms such as linear and log-log.

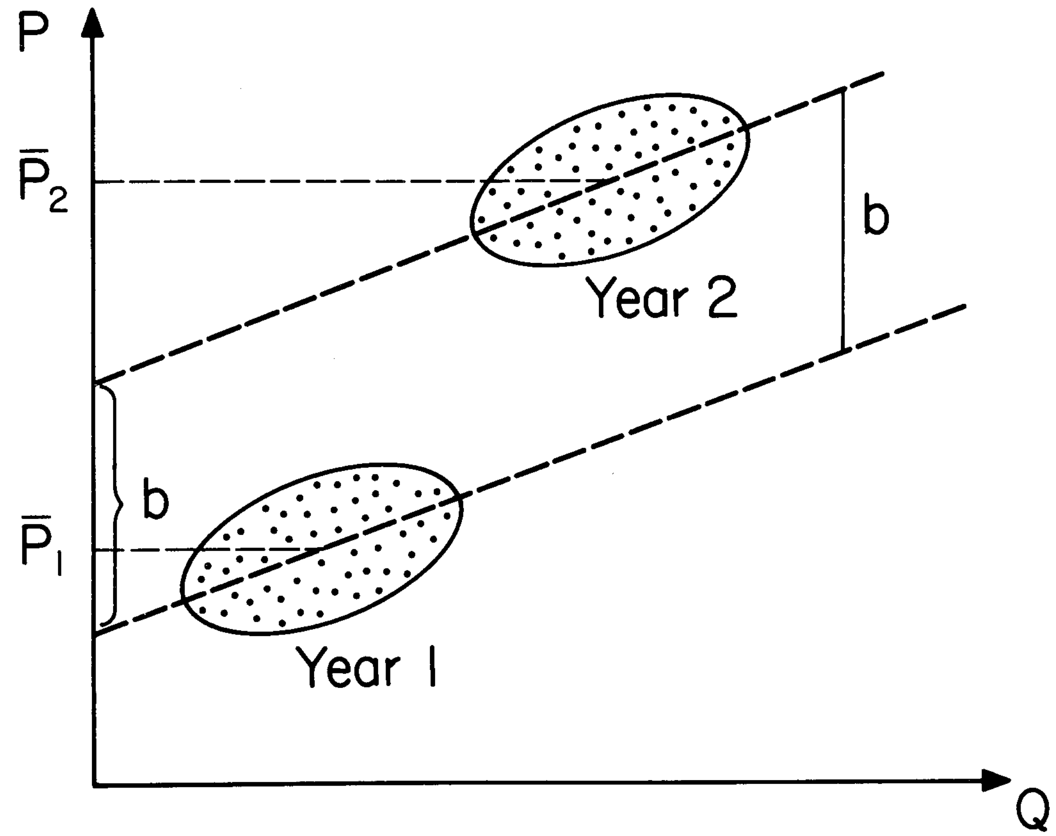

Figure 1. Adjustment of Douglas-Fir Price Change for Change in Sale Quality by the Dummy Variables Method. Case with One Quality Characteristic Q and Two Years. $\bar{P}_2 - \bar{P}_1$ is the Unadjusted Price Change, b is the Adjusted Price Change.

stant. Each price equation has the expression:

$$(8)\quad P_i = a_{ot} + a_{lt} Q_{li} + \dots a_{kt} Q_{ki} + c_t Y_i + u_i \quad i = 1, \dots, n_t + n_{t+1}$$

where

$Y_i = 1$ iff observation i falls in year t + 1

$Y_i = 0$ otherwise.

There is one such equation for each t = 2, ..., T and therefore T − 1 values of $\hat{c}_t$ measuring the pure price change between year t and t + 1. The price of Douglas-fir on the average base-year sale, had it been sold in year t would then be:

$$(9)\quad \hat{P}^1_t = \bar{P}_1 + \hat{c}_2 + \dots + \hat{c}_t$$

The series of pure price and quality changes are then computed by applying formulae (5), (6) and (7).

Method III

Pursuing the idea of allowing for changes in weights, [Dhrymes 1971] proposes to estimate a regression equation like (2) for each year t:

$$(10)\quad P_i = a_{ot} + a_{lt} Q_{li} + \dots + a_{kt} Q_{ki} + u_i \quad i = 1, \dots, n_t$$

where $a_{ot}, \ldots, a_{kt}$ are the coefficients of the price equation for Douglas-fir sold in year t.

Let $\bar{Q}_{11}, \ldots, \bar{Q}_{k1}$ be the characteristics of the average sale in the base period. Had it been sold in year t, it would have carried a price which is estimated as:

$$(11)\ \hat{P}_t^1 = \hat{a}_{ot} + \hat{a}_{1t}\bar{Q}_{11} + \ldots + \hat{a}_{kt}\bar{Q}_{k1},$$

$$t = 1, \ldots, T.$$

The pure price changes between year 1 and year t are then computed using equation (5). They are the changes between year 1 and year t of the price of Douglas-fir on a sale with constant characteristics. Application of equations (6) and (7) then leads to the quality component of the unadjusted price change.

Method IV

Method IV, also suggested by [Dhrymes 1971] is symmetric to method III. Whereas Method III held constant the quality of Douglas-fir sales and let the implicit prices vary over time, Method IV holds the implicit prices constant and lets quality vary. Method IV first calculates the part of price change due only to quality changes. The pure price change is then equal to the total change less the quality-related change.

Let $\hat{a}_{o1}, \ldots, \hat{a}_{k1}$ be the estimated coefficients of regression (10) for the base year, and $\bar{Q}_{1t}, \ldots, \bar{Q}_{kt}$ be the characteristics of the average sale in year t. Had this sale occurred in the base year, the price of Douglas-fir would have been $\hat{P}_1^t$ such that:

$$(12)\ \hat{P}_1^t = \hat{a}_{o1} + \hat{a}_{11}\bar{Q}_{1t} + \ldots + \hat{a}_{k1}\bar{Q}_{kt}$$

The difference between $\hat{P}_1^t$ and the mean price of Douglas-fir in the base year, $\bar{P}_1$, is then an estimate of the quality component of price change between year 1 and year t, QP_{1t}:

$$(13)\ QP_{1t} = \hat{P}_1^t - \bar{P}_1,\ t = 2, \ldots, T$$

and the pure price change between year 1 and year t, PP_{1t}, is:

$$(14)\quad PP_{1t} = TP_{1t} - QP_{1t} = \bar{P}_t - \hat{P}_1^t, ..$$

$$t = 2, \ldots, T$$

The Data

The analysis of price-quality relationships reported below is based on a random sample of 425 U.S. Forest Service timber sales in the Pacific Northwest (U.S. Forest Service region 6) during the period 1968 to 1978. Sales selected were sold using either an oral or sealed bid auction. No attempt was made to distinguish between set-aside or sealed bid sales.[4] All data originated from U.S. Forest Service form 2400-17, "Report of Timber Sale." This was dictated by the need to have data for a large number of sales, over a long time interval, in a standard form, and at low cost. To minimize the amount of data needed, only yearly price indices were computed. The purpose, noted earlier, was to determine if any bias had resulted from ignoring quality changes during the eleven-year period of study, and to compare the results obtained by the four adjustment methods.

Preliminary estimation of various models suggested by previous work was undertaken. The variables used in the last steps of the study are reported in Table 1. In all regression equations, the unadjusted price of Douglas-fir is defined by the winning firm's bid for that species (DHI).

The variables PRD2S to PRGOOD measure the share of Douglas-fir timber of a

[4]Most timber is sold by an auction method. Bidding on set-aside sales is restricted to firms with less than 500 employees. [Haynes 1979] finds that there is no difference in bid prices between set-aside and unrestricted sales when data are aggregated over the Douglas-fir region.

particular grade relative to the total volume of Douglas-fir on a sale.[5]

PERDF is the share of all Douglas-fir, relative to the total sale volume of PRH to PRPAM, given the relative share of other species. MILES is an estimate of the distance an average firm must transport the cut timber in order to process it. It is estimated by the Forest Service prior to the sale and is only an average figure since the location of the winner's mill is not known at that time. PERMRD and TEMPRD are volume weighted estimates of the permanent and temporary road construction necessary to extract the timber. The geographic location of a sale is represented by dummy variables (F3 to F18) taking the value 1 if a sale occurred in a particular national forest, zero otherwise. Finally, in applying Methods I and II, the dummy variables Y68 to Y78 were used, taking the value one if a sale occurred in a specific year, zero otherwise.

[5]The Forest Service uses seven grades: #1 peeler, #2 peeler, #3 peeler, special peeler, #1 sawlog, #2 sawlog, and #3 sawlog. General characteristics of this system are that #1 peeler and sawlog, and #2 peeler are usually of higher quality than the other grades. Furthermore, the minimum recoverable product is 50 percent for peelers compared to 33 percent for sawlogs. This grading system does not constitute a uniformly increasing quality ranking. For example, a #3 peeler may be inferior to a 2 sawlog, despite the fact that peeler logs are usually of better quality than sawlogs. This type of inadequacy and ambiguity has led the Forest Service to devise new grading guidelines [Burck, Lane and Woodfin] but they have not yet been adopted.

Empirical Price Equations

Equation (3) was estimated by ordinary least squares using the data described in the previous section and the variables listed in Table 1. The results appear in the first column of Table 2.

Some of the original variables were omitted from the final model because they did not seem important in determining the price of Douglas-fir. Omission of relevant variables would bias the remaining coefficients. On the other hand, inclusion of irrelevant variables would lead to inefficient estimates [Maddala, p. 157]. In this case it was deemed preferable to omit variables which had large standard errors and signs which did not correspond to a-priori expectations. The over-all F ratio for omitted variables was 0.86, which is much smaller than the critical $F_{.95} = 1.80$. Omission of these variables decreased the stan-

TABLE 1. Variables used to Compute a Quality-Adjusted Price of Douglas-Fir Stumpage.

Variable Name	Definition
DHI	Winning bid for Douglas-fir, in dollars per thousand board feet
PRD2S	Share of #2 sawlog relative to all Douglas-fir
PRD3S	Share of #3 sawlog relative to all Douglas-fir
PRD3PS	Share of #3 peeler and special peeler relative to all Douglas-fir
PRGOOD	Share of #1 peeler, #2 peeler, #1 sawlog and peeler relative to all Douglas-fir
PERDF	Share of Douglas-fir relative to all timber
DNDF	Density of Douglas-fir, in thousand board feet per acre of entire sale
PRH	Share of western hemlock relative to all timber
PROTH	Share of all other species relative to all timber
PRPAM	Share of per-acre material relative to all timber
MILES	Average hauling distance from sale site to representative mill
PERMRD	Estimated permanent road construction, in miles per thousand board feet of timber
TEMPRD	Estimated temporary road construction, in miles per thousand board feet of timber
F3, F5, F6, F9, F10, F11, F12, F15, F18	Dummy variables identifying sales in the following national forests: Gifford Pinchot, Mount Baker-Snoqualmie, Mount Hood, Olympic, Rogue River, Siskiyou, Siuslaw, Umpqua, and Willamette, respectively
Y68 to Y78	Dummy variables identifying sales having occurred in each year from 1968 to 1978

dard errors of the others, which is consistent with an increase in efficiency. Efficiency is an important criterion in this study, due to the small samples used by methods II, III and IV. Inefficient estimates may change drastically in magnitude and sign from year to year, which would imply that a specific characteristic, say the length of road to be built, is an asset in one year and a liability the next. This problem was reduced by the approach

TABLE 2. Douglas-Fir Price Equations, for all Eleven Years 1968 through 1978 and for Two Years Taken Together From 1973 to 1978.[a]

Coefficients of	Years 1968-1978	1968-1969	1969-1970	1970-1971	1971-1972	1972-1973
PRD2S	50.36 (1.93)	26.92 (.83)	30.31 (.36)	63.15 (3.33)	82.79 (3.30)	115.90 (2.83)
PRD3PS	66.12 (2.54)	21.57 (.71)	43.79 (.53)	79.87 (4.47)	767.56 (3.08)	118.77 (2.87)
TEMPRD	−7663.8 (−3.2)	−5199.1 (−1.0)	−8380.4 (−1.4)	−1324.8 (−.8)	−17.77 (−.01)	−711.24 (−.18)
DENDF	.08 (3.99)	−.01 (−.36)	.02 (.84)	.03 (3.13)	.04 (2.16)	.07 (1.60)
PERDF	36.04 (2.38)	−14.97 (−.85)	24.57 (.86)	−7.23 (−.67)	−20.88 (−1.36)	−36.12 (−1.59)
PROTH	35.71 (1.86)	−23.50 (−.74)	38.10 (1.10)	14.39 (1.09)	28.99 (1.64)	45.76 (1.76)
F10	−33.79 (−2.70)	−2.51 (−.12)	−9.49 (−.41)	4.85 (.61)	−5.98 (−.53)	−27.47 (−1.50)
F18	39.73 (4.39)	−7.71 (−.77)	−2.82 (−.14)	−3.19 (−.48)	−8.00 (−.65)	−65.07 (−1.68)
Constant	−37.83 (−1.63)	47.71 (2.07)	29.68 (.40)	−15.23 (−.85)	−4.60 (−.21)	−4.58 (−.14)
Y69	24.89 (1.13)	34.26 (3.93)				
Y70	−15.80 (−.86)		−36.31 (−2.97)			
Y71	6.47 (.43)			13.58 (2.81)		
Y72	39.00 (2.65)				22.9 (3.6)	
Y73	76.70 (4.26)					38.79 (3.53)
Y74	119.42 (8.40)					
Y75	106.92 (7.48)					
Y76	107.51 (7.16)					
Y77	136.18 (9.27)					
Y78	169.93 (12.01)					
R^2	.55	.51	.52	.49	.39	.43
n	389	41	29	56	80	61

TABLE 2 (Continued)

Coefficients of	Years				
	1973-1974	1974-1975	1975-1976	1976-1977	1977-1978
PRD2S	122.21	25.40	−37.75	34.05	104.77
	(1.89)	(.44)	(−.73)	(.58)	(1.23)
PRD3PS	146.25	106.16	81.89	−8.28	111.63
	(2.16)	(1.67)	(1.53)	(−.14)	(1.35)
TEMPRD	−14245.8	−12640.0	−13823.0	−2968.3	−11790.4
	(−2.4)	(−2.7)	(−2.6)	(−.4)	(−2.0)
DENDF	.06	.12	.24	.17	.13
	(1.09)	(2.37)	(4.29)	(3.21)	(2.66)
PERDF	.15	51.82	32.07	94.03	140.33
	(.01)	(1.62)	(.98)	(2.72)	(3.94)
FOR10	−60.34	−59.67	−51.72	−44.85	−45.44
	(−1.84)	(−1.91)	(−1.63)	(−1.27)	(−1.65)
FOR18	31.16	61.59	60.53	66.80	59.76
	(1.28)	(3.23)	(3.12)	(3.54)	(3.23)
PROTH	3.54	43.75	79.70	93.51	64.00
	(.07)	(.96)	(1.81)	(1.89)	(1.32)
Constant	16.31	67.63	93.93	34.93	−26.81
	(.33)	(1.43)	(2.11)	(.71)	(−.36)
Y74	46.19				
	(2.38)				
Y75		−9.34			
		(−.62)			
Y76			−9.34		
			(−.62)		
Y77				28.81	
				(1.76)	
Y78					37.98
					(2.52)
R^2	.39	.34	.40	.36	.47
n	68	97	86	87	96

[a]See Table 1 for definition of variables. Numbers in parenthese are t statistics. R^2 is the coefficient of determination and n is the number of observations.

adopted here, but not eliminated completely, as will be seen from the empirical results.

High standard errors of variables could be due to multicollinearity. There is no rigorous test for multicollinearity [Maddala, p. 186], but it did not appear to be serious in this case. The highest partial correlation (−0.67) occurred between the variables PR2DS and PRD3PS, both of which were left in the final model. All other partial correlation coefficients were much smaller. Another useful diagnostic of multicollinearity, omission of a few observations from the sample, changed the results very little.

The first column in Table 2 shows that the price of Douglas-fir is systematically and positively related to the share of #2 sawlog, #3 peeler, and special peeler logs relative to all Douglas-fir (PRD2S, PRD3PS), the density of Douglas-fir per acre (DENDF), the share of Douglas-fir in total sale (PERDF), and the share of other species excluding hemlock and per-acre-material (PROTH). The price of Douglas-fir is negatively affected by the estimated amount of temporary roads per MBF of sale volume which must be built (TEMPRD). Finally, sales in the Rogue River National Forest tended to carry systematically lower prices, while those in the Willamette were significantly higher. Together with the yearly dummy variables, the quality variables explain some 55 percent of the variance in Douglas-fir stumpage prices over the period 1968-1978.

The coefficients of the yearly dummies in the first column of Table 2 correspond to the $\hat{b}_t$ coefficients in equation (3). Their value indicates by how much Douglas-fir prices, adjusted for quality change, differed in any year from the price in 1968. For example, in 1970 the pure price was \$15.80 per thousand board feet lower than in 1968, but this difference was not significantly different from zero at the 95 percent confidence level.

Table 2 also shows the regression results for Method II. One regression was estimated for each pair of adjacent years between 1968 and 1978. The functional form and variables used were the same as in Method I and the same for each pair of years. The coefficients of the yearly dummies correspond to the $\hat{c}_t$ coefficients in equation (8) and measure the change in sale price between two consecutive years, holding quality constant. Table 2, for example, indicates that according to Method II, the rise in pure price which occurred between 1968 and 1969 was about 34 dollars per thousand board feet and significantly different from zero, while no significant price change occurred between 1974 and 1975 or 1975 and 1976.

The data in Table 2 clearly show the instability of coefficients over time; they change not only in magnitude but also in sign. This problem is accentuated when the yearly regressions, used by Methods III and IV, are estimated. These results are in Table 3.

Chow-type F-tests of the restrictive assumptions imposed by Methods I and II were performed (using a 95 percent significance level). The null hypothesis of constant coefficients across the entire sample period was rejected when compared with the alternative of letting them vary each year. On the other hand, it seemed acceptable to aggregate data over adjacent years. The constant coefficients hypothesis was rejected for only one (1976-1977) of the ten pairs of years.

Main Results and Discussion

The empirical price equations in Tables 2 and 3 were used to decompose the annual change of Douglas-fir price into a pure price change component and a quality change component. The base year was 1968. The additional data needed, i.e., the evolution of the mean characteristics of the sales between 1968 and 1978, appear in Table 4. No clear trend is apparent, except for the general increase in the price of Douglas-fir stumpage (DHI).

The results obtained by the four methods appear in Table 5. They are generally quite different. All, however, indicate that the average annual change in price due to quality changes over the sample period has been very small and not statistically different from zero. For example, Method I indicates that because of changes in Douglas-fir stumpage quality, the price has declined at an average rate of \$0.10 per year, but the standard error is \$3.2. As a result, over the entire period the average annual price change is the same, about \$17.0 per year, whether the price is adjustd or not, regardless of the adjustment method used.

The data in Table 5 indicate that variations in timber sale characteristics may play a more important role in year-to-year price fluctuations. For example, according to Method I, \$10.70 of the unadjusted \$35.60 rise in price which occurred between 1968 and 1969 was, in fact, due to quality differences. On the other hand, between 1970 and 1971 the unadjusted price rise of \$5.30 corresponded, in effect, to a pure price increase of \$22.30, due to a decine in sales quality accounting for \$17.00.

Unfortunately the magnitude and sign of these year-to-year quality effects differ depending on the adjustment method. Given the specific data set used here, Method I is

TABLE 3. Douglas-Fir Price Equations, for Each Year from 1968 to 1978.

	Coefficients of Quality Variables										
Year	PRD2S	PRD3PS	TEMPRD	DENDF	PERDF	PROTH	FOR10	FOR18	Constant	R^2	n
1978	80.33	218.65	−14300.4	.23	167.44	98.62	−28.04	50.65	−36.02	.53	53
	(.70)	(1.90)	(−1.9)	(2.36)	(2.29)	(1.33)	(−.76)	(1.70)	(−.33)		
1977	60.02	−67.59	10472.3	.12	138.06	26.13	−43.10	85.39	39.34	.56	43
	(.47)	(−.58)	(.9)	(2.37)	(3.84)	(.36)	(−.96)	(4.00)	(.38)		
1976	−22.44	108.63	−17765.6	.29	−1.72	110.67	−59.44	39.68	89.15	.39	38
	(−.29)	(1.24)	(−1.6)	(2.55)	(−.03)	(1.56)	(−1.13)	(1.28)	(1.36)		
1975	−58.45	79.70	−15216.8	.20	38.25	1.10	−36.94	101.11	108.6	.50	48
	(−.63)	(.82)	(−2.3)	(3.00)	(.99)	(.02)	(−.88)	(3.59)	(1.4)		
1974	110.95	122.90	−14567.5	.03	24.99	−9.20	−55.53	32.18	65.66	.29	49
	(1.37)	(1.35)	(−2.1)	(.43)	(.42)	(−.12)	(−1.16)	(1.14)	(1.02)		
1973	190.47	172.43	−2918.42	.23	−82.9	68.56	−40.67		−4.49	.72	19
	(1.80)	(1.98)	(−.26)	(2.39)	(−2.0)	(1.09)	(−1.05)		(−.07)		
1972	101.14	58.52	−297.78	.02	−18.61	32.49	−19.10	−73.18	17.57	.29	42
	(2.19)	(1.17)	(−.06)	(.37)	(−.69)	(1.12)	(−.91)	(−1.9)	(.44)		
1971	59.41	81.64	−1464.5	.04	−24.65	4.12	12.63	1.00	12.11	.67	38
	(3.37)	(5.0)	(−1.0)	(3.29)	(−2.16)	(.29)	(1.55)	(.15)	(.73)		
1970	−76.72	−76.45	−33234.0	.02	49.48	52.00	−8.16	1.21	74.36	.46	18
	(−.82)	(−.78)	(−1.4)	(.70)	(1.69)	(1.63)	(−.42)	(.07)	(.98)		
1969	263.11	226.82	−14316.5	−.05	−105.6	−95.74			−20.41	.30	11
	(.54)	(.59)	(−.6)	(−.35)	(−.3)	(−.17)			(−.05)		
1968	15.19	12.63	815.41	−.02	−12.71	−38.52	6.61	−7.42	53.60	.28	30
	(.65)	(.55)	(.15)	(−.71)	(−.90)	(−1.65)	(.45)	(−1.04)	(3.31)		

[a]See Table 1 for definition of variables. Numbers in parentheses are t statistics.

TABLE 4. Evolution of Mean Value of Timber Sale Characteristics and Douglas-Fir Price During the Period 1968 to 1978.[a]

Variable	Year										
	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
PRD2S	.56	.60	.63	.54	.54	.58	.53	.56	.48	.56	.61
PRD3PS	.20	.30	.22	.25	.25	.20	.27	.25	.30	.28	.23
TEMPRD	.0004	.0007	.0003	.0009	.0006	.0005	.0007	.0005	.0006	.0004	.0007
DENDF	175.7	225.1	313.6	185.3	158.4	98.6	171.3	133.8	118.3	160.8	137.5
PERDF	.70	.86	.74	.71	.62	.66	.67	.69	.66	.66	.63
PROTH	.11	.08	.15	.15	.19	.11	.15	.09	.14	.08	.22
FOR10	.10	.00	.11	.11	.10	.11	.08	.06	.08	.05	.15
FOR18	.20	.00	.11	.16	.02	.00	.22	.13	.26	.28	.15
DHI	48.34	84.00	49.09	54.44	80.94	110.02	170.53	152.24	155.49	191.83	216.04

[a]See Table 1 for definitions of variables.

attractive because it leads to coefficients of quality characteristics which have the expected signs and small standard errors. However, it assumes that these coefficients do not change over time, an assumption which is not supported by the data. Method IV has the same problem since it relies on constant coefficients estimated in the base year. In practical applications Method I has an additional inconvenience. The entire series would have to be changed each time an updating is done since the new data would change all the coefficients in equation (3).

In principle, Methods II and III have the advantage of allowing for continuous changes in weights. However, unless there are sufficient observations available in each period (month, year, or quarter) the changes in weights will tend to reflect sampling errors rather than genuine changes in the valuation of sale characteristics by buyers. From that point of view Method II, which pools two adjacent periods, is preferable to Method III, which relies on a single period. For the present purpose of developing a yearly price series, pooling consecutive years appeared statistically acceptable.

It appears that the choice of a single method very much depends on the purpose. For example, the results indicate that the adjustment of stumpage price for quality differences is more important for short-term periods. It would become especially critical for monthly or quarterly statistics since few sales occur during such short time spans, especially during the winter months. These sales may vary widely in quality, and some procedure should be used to reduce them to a single standard and thus derive a price statistic reflecting the change over time of a commodity of constant quality.

In this last case Methods II and III would be ruled out because of the small number of observations in each period. The most practical way would then be to use a variation of Method IV. It involves estimating a single price equation for a sufficiently long base period and using it to price the sales occurring every month or quarter. The base period

TABLE 5. Annual Change of Douglas-Fir Stumpage Price Decomposed into Pure Price (PP) and Quality (QP) Components by Different Methods.[a]

		Method I		Method II		Method III		Method IV	
Year	Unadjusted Change	PP	QP	PP	QP	PP	QP	PP	QP
1968									
	35.6	24.9	10.7	34.3	1.3	23.8	11.8	34.3	1.3
1969									
	−34.9	−40.7	5.8	−36.2	1.3	−27.0	−7.6	−31.5	−3.4
1970									
	5.3	22.3	−17.0	13.5	−8.2	6.6	−1.3	3.7	1.6
1971									
	26.5	32.5	−6.0	22.9	3.6	10.5	16.0	26.1	.4
1972									
	29.1	37.7	−8.6	38.8	−9.7	57.6	−28.5	25.4	3.7
1973									
	60.5	42.7	17.8	46.2	14.3	48.4	12.1	64.7	−4.2
1974									
	−18.3	−12.5	−5.8	−9.2	−9.1	−4.5	−13.8	−21.6	3.3
1975									
	3.3	.6	2.7	−9.3	12.6	−8.9	12.2	6.1	−2.8
1976									
	36.3	28.7	7.6	28.8	7.5	41.6	−5.3	34.1	2.2
1977									
	24.2	33.7	−9.5	38.0	−13.8	24.5	−.3	27.2	−3.0
1978									
Mean	16.8	17.0	−0.1	16.8	−0.0	17.3	−0.5	16.9	−0.1
	(8.5)	(8.0)	(3.2)	(8.1)	(3.0)	(8.1)	(4.2)	(8.5)	(2.8)

[a]All data are in dollars per thousand board feet. Numbers in parentheses are standard errors of mean annual change.

could be changed at long intervals, say every ten years, to allow for changes in weights.

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