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Valuing a Log: Alternative Approaches

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Abstract

The gross value of products that can be manufactured from a tree is the starting point for a residual-value appraisal of a forest operation involving the harvest of trees suitable for making forest products. The amount of detail in a model of gross product value will affect the statistical properties of the estimate and the amount of ancillary information that is provided. Seven data sets from forest product recovery studies of western conifers were used in the evaluation of three models of gross product value. The evaluation of these models was based on the need for information and the statistical properties of the estimators. The most detailed method provided additional information, but at some loss in the precision and accuracy of the prediction of gross value of products from a log.

Keywords: Residual-value appraisal, log value, alternative approaches.

Introduction

Residual value is a common approach used to estimate the value of forest operations involving the removal of trees suitable for making wood products (Duerr 1993). The residual-value approach begins with an estimate of the gross value of products that can be produced from the logs of a tree. This approach was once used by the USDA Forest Service for appraising timber sales but was abandoned in favor of a transactions-evidence appraisal system. Residual-value methods are especially helpful for understanding the components of costs and revenues associated with a timber appraisal and are therefore useful in research applications.

The purpose of this study was to evaluate three models for estimating the gross product value that is required for using the residual-value approach. All three models were based on data from empirical lumber recovery studies but use different amounts of detail in deriving the estimates. The evaluation of the models was based on the need for information and the statistical properties of the estimators.

The seven empirical lumber recovery data sets used in this evaluation come from lumber recovery studies (Stevens and Barbour 2000). Each data set provides (1) an estimate of gross product value per cubic foot of log for a species (or species group) for a particular type of lumber product and set of product prices; (2) the proportion of the volume of the log ending up in three products: lumber, chips, and residues; (3) the proportion of lumber that falls in each lumber grade; and (4) diameters and lengths of the logs. These data are available for each of the logs in the data set. These values and transformations of them are used in regression equations to estimate gross product value.

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Data and Methods

A description of the database used in this study is available in Stevens and Barbour (2000). Logs for this study include ponderosa pine (*Pinus ponderosa* Dougl. ex Laws) from the intermountain West and Douglas-fir (*Pseudotsoga menziesii* (Mirb.) Franco), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and true fir species (*Abies*) from western Oregon and Washington. Table 1 provides a description of the data used in the study. The logs studied in this analysis are from small-diameter trees with an average small-end diameter ranging from 8.8 to 10.5 inches, average taper ranging from 0.12 to 0.17 inch per foot of log, and average log length ranging from 14.7 to 23.7 feet. We believe that these three variables are the most important in determining the value of a log. Although log grade and knots are key variables in determining the value of logs, we could not include these variables in our models because relevant data are not available in the data sets nor would it be available in potential applications of the models.

In pricing lumber to determine the gross product values for logs in the database, volumes in each of the lumber grades were multiplied by the 1999 prices. For the detailed method, lumber grades were combined into a workable number of grade groups as shown in table 1 and weighted average prices were applied for these grade groups (Chmelik et al. 1999). For ponderosa pine, 1999 average prices were for dry surfaced lumber from the inland region (WWPA 2000b). For Douglas-fir, 1999 average prices were for green-surfaced lumber from the coast region (WWPA 2000a). For western hemlock and true firs (hem-fir), prices were for dry hem-fir lumber from the coast region (WWPA 2000a).

Lumber volumes were measured in board feet, and the corresponding prices in dollars per board foot were applied. The chips and residues (sawdust and planer shavings) portions produced from these logs were measured in cubic feet of solid wood equivalent (SWE), and the corresponding prices in dollars per cubic foot were used in all three methods. Details of the calculation of the gross product value of logs in the database are shown below.

Calculated Gross Product Value of Logs

The gross product value of logs in dollars per cubic foot of log volume was calculated by summing values of detailed lumber grades, chips, and residues portions as follows:

$$\text{Gross value} = \frac{\left(\sum_{i=1}^{n} L_i \times P_i\right) + C \times P_c + R \times P_r}{CF_{LOG}}, \tag{1}$$

where $\sum_{i=1}^{n} L_i \times P_i$ is the sum of value of lumber in various grades; i = 1 to 48 for ponderosa pine, and 1 to 16 for Douglas-fir, western hemlock, and true firs; $C \times P_c$ is the value of chip portion; $R \times P_r$ is the value of residues portion in a log; L_i is the quantity of lumber in board feet in the i-th grade of lumber; C and R are quantities of chips and residues in cubic feet SWE; P_i is price of lumber in dollars per board foot for the i-th grade of lumber; P_c and P_r are prices of chips and residues in dollars per cubic foot SWE; and CF_{LOG} is the total volume of the log in cubic feet. These values were calculated for each log in the seven data sets and were the basis of comparison between the alternative methods of estimation of gross product value of logs.

Table 1—Details species, products, logs, lumber grades, and average values of variables used in the study

Tree species and lumber type	No. of logs	No. of lumber grades[a]	Average value of variables SED[b] (D)	Taper (T)	Length (H)
			- - - - *Inches* - - - -		*Feet*
Ponderosa pine:					
Old growth, Dimension	66	48	10.44	0.14	15.56
Old growth, Appearance	266	48	10.48	.15	14.49
Young growth, Dimension	178	48	8.79	.16	15.11
Young growth, Appearance	418	48	8.93	.17	14.68
Douglas-fir: Dimension	1,517	16	9.65	.13	18.89
Western hemlock: Dimension	321	16	8.96	.12	23.64
True firs: Dimension	1,663	16	10.00	.17	15.49

[a] There was a small amount of volume in some of these studies that was originally graded into grades that are no longer commonly used, and that volume was reassigned to the current most nearly equivalent grade.
[b] SED = small-end diameter.

The three alternative methods are (1) direct method: value was estimated directly by regressing the actual value of log per cubic foot on small-end diameter in inches, taper in inches per foot of log length, and log length; (2) intermediate method: value per cubic foot was estimated by using regressions for lumber recovery factor (board feet per cubic foot of log) for lumber (LRF), average price per board foot, and recovery proportions for chips and residues (in cubic feet of SWE per cubic foot of log); and (3) detailed method: value per cubic foot was estimated by using regressions for detailed grade recovery equations, LRF, and recovery proportions of chips and residues. In all three methods, a value of the log in dollars per cubic foot was estimated for comparison. These three methods are described below.

Direct Method

The simplest model of gross product value for logs was based on a regression of the value per cubic foot of log as a function of log small-end diameter, taper (computed from log diameters and length), and length of log. This provided a single regression equation for a log manufactured into the specified lumber product; for example, visually graded Douglas-fir Dimension lumber. This will be referred to as the direct method. In this method, the value of a log was estimated by using an equation of the following form:

$$\text{Value (direct)} = f(D, T, H)\,, \qquad (2)$$

where D is small-end diameter in inches, T is taper in inches per foot of log, and H is length of log in feet.

The dependent variable used in the equation came from the gross product value of logs calculated in equation (1). Various forms of small-end diameter (D, D^2, $1/D$, and $1/D^2$), taper (T and T^2), and length of log (H, H^2, $1/H$, and $1/H^2$) were tried in a step-wise regression equation, and the equation with the highest R^2 was selected, (the p-values selected for entry and retention of independent variables are 0.15 and 0.10, respectively). If more than one form of a variable were retained in the final selection of the step-wise regression, two forms for the small-end diameter, and one form each for taper and length of log were selected based on highest partial R^2. In this method, there is only one prediction equation. By definition, the mean value of log estimated from this direct method is always equal to the mean of the gross product value of log calculated in the previous section. In this method, the only information predicted is the value of log in dollars per cubic foot based on the predictive regression equation. No other information is derived from this method.

Intermediate Method

An approach intermediate in complexity was based on regressions of the average value per board foot of lumber from the log and the proportion of log volume going into lumber, chips, and residues (as in the previous method). These regressions also were based on log small-end diameter, taper, and length. These estimates were combined with prices for lumber, chips, and residues to get gross product value per cubic foot of log. This method does not involve equations for the proportion of lumber in each grade or grade group and is therefore unable to provide any information about the quality of lumber other than its average value per board foot. This will be referred to as the intermediate method.

This method uses predictive equations for LRF, recovery proportion for residues (R_{rp}), price in dollars per board foot of lumber (P_{bf}), and recovery proportion of lumber (L_{rp}), which were estimated as follows:

$$LRF = f(D, T, H), \quad (3a)$$

$$R_{rp} = f(D, T, H), \quad (3b)$$

$$P_{bf} = f(D, T, H), \text{ and} \quad (3c)$$

$$L_{rp} = f(D, T, H), \quad (3d)$$

where *LRF* is the lumber recovery factor (board feet of lumber per cubic foot of log volume), *D* is small-end diameter in inches, *T* is taper in inches per foot of log, *H* is the length of log in feet, R_{rp} is proportion of the log that ends up as residues, P_{bf} is price of lumber in dollars per board foot, and L_{rp} is the proportion of log that ends up as lumber (CF/CF of log volume). As in the direct method, various forms of *D*, *T*, and *H* were tried in a step-wise regression, and the equation with the highest R^2 value was selected. The recovery proportion of chips (C_{rp}) in the log was estimated by subtracting recovery proportions of lumber (L_{rp}) and residues (R_{rp}) from 1 ($C_{rp} = 1 - L_{rp} - R_{rp}$). Here, the distinction between *LRF* and L_{rp} should be noted. The unit of LRF is the number of board feet per cubic foot of the part of log volume that is made into lumber, whereas L_{rp} is the proportion of log volume in cubic feet that is converted into lumber from the total volume of log in cubic feet. The total volume of log is composed of L_{rp}, C_{rp}, and R_{rp}.

In this method, the value of a log in dollars per cubic foot was estimated as:

$$\begin{aligned} \text{Value (intermediate)} = \; & LRF \times P_{bf} \text{ (Lumber portion)} \\ & + R_{rp} \times P_r \text{ (Residues portion)} \\ & + C_{rp} \times P_c \text{ (Chips portion)}, \end{aligned} \quad (4)$$

where *LRF* is lumber recovery factor in board feet per cubic foot of log volume, P_{bf} is price of lumber in dollars per board foot, R_{rp} and C_{rp} are recovery proportions of residues and chips in the total volume of log, and P_r and P_c are prices for residues and chips in dollars per cubic foot SWE.

In this method, there are four predictive equations; i.e., for *LRF*, recovery proportion of residues (R_{rp}), price of lumber per board foot (P_{bf}), and recovery proportion of lumber (L_{rp}). Thus, in addition to the estimated value of a log, information can be generated on LRF; recovery proportions of lumber, residues, and chips; and price of lumber in dollars per board foot based on the predictive equations.

Detailed Method

The most complex model of gross product value was based on regressions of the proportion of lumber in each of several grade groups and the proportion of log volume going into lumber, chips, and residues. These regressions were based on log small-end diameter, taper, and length. These estimates were combined with prices for chips, residues, and each grade group of lumber to get gross product value per cubic foot of log. This method provided information not available from the other methods but required many more equations. This will be referred to as the detailed method.

In this method, the volume of lumber in board feet for each of the grade groups for each log is estimated as:

$$G_i = f(D, T, H) \quad \text{for all } i \ (i = 1, 2, \ldots, \mathrm{L}) \tag{5a}$$

$$LRF = f(D, T, H) \tag{5b}$$

$$L_i = G_i \times LRF \times CF_{LOG} \quad \text{for all } i \ (i = 1, 2, \ldots, \mathrm{L}) \ , \tag{5c}$$

where G_i are the proportions of lumber in lumber grade groups, *LRF* is the lumber recovery factor (board feet per cubic foot of log) for each log, L_i is the volume of lumber in board feet in the log in the *i*-th grade, CF_{LOG} is the total volume of a log in cubic feet, and L is the total number of lumber grades produced from the logs.

The value of the log in the detailed method in dollars per cubic foot was estimated as:

$$\text{Value (detailed)} = \frac{\left(\sum_{i=1}^{n} L_i \times P_i\right) + C \times P_c + R \times P_r}{CF_{LOG}} \ , \tag{6}$$

where $\sum_{i=1}^{n} L_i \times P_i$ is the lumber portion, $C \times P_c$ is the chips portion, $R \times P_r$ is the residues portion, and CF_{LOG} is the log volume, P_i are the weighted average prices of *i*-th lumber grade group in the detailed method, and P_c and P_r are prices for chips and residues in dollars per cubic foot SWE.

The detailed method provides extensive information on the volumes, lumber grades, and values of all the products derived from the logs manufactured from each tree based on the predictive equations and the prices provided. This detailed information can often be useful for various purposes. This method was adopted in the financial evaluation of ecosystem management activities (FEEMA) and FEEMA WS (westside) software developed by the USDA Forest Service, Pacific Northwest Research Station (Fight and Chmelik 1998). This software and documentation is available at http://www.fs.fed.us/pnw/data/soft.htm.

Evaluation Criteria

The value of a log in dollars per cubic foot was estimated for each log in all of these methods for ponderosa pine, Douglas-fir, western hemlock, and true firs. The estimated values obtained in the three models were compared with the actual gross value of the log with a specified set of market prices. For this purpose, statistical measures such as average deviation and average absolute deviation of the predicted values in the direct, intermediate, and detailed methods from the actual gross value of logs were derived. Average deviation indicated the estimated bias, and average absolute deviation measured the estimated accuracy (Max et al. 1985) and were derived as:

$$\text{Average deviation} = \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)}{n}, \tag{7a}$$

$$\text{Average absolute deviation} = \frac{\sum_{i=1}^{n}| y_i - \hat{y}_i |}{n}, \text{ and} \tag{7b}$$

$$\text{Average deviation squares} = \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n}, \tag{7c}$$

where y_i is the actual value of a log; $\hat{y}_i$ is the estimated value of a log in the direct, intermediate, or detailed methods; and n is the number of observations.

These three models also were compared by model selection criteria, Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC). These criteria are similar to R^2 in that these reward good fit but also penalize the loss of degrees of freedom (Greene 1993). The difference between these two criteria is that BIC imposes a larger penalty for the extra coefficients. The information criteria are estimated as:

$$\text{AIC} = ln(\hat{\sigma}^2) + (2k / n) \tag{8a}$$

$$\text{BIC} = ln(\hat{\sigma}^2) + (k\, ln(n) / n), \tag{8b}$$

where $\hat{\sigma}^2$ is RSS/n, RSS is the estimated residual sum of squares obtained by summing the squared residuals between actual value that was estimated under calculated gross product value and the predicted values obtained in the different methods (i.e., direct, intermediate, and detailed methods), n is the number of observations, and k is the number of estimated parameters in the entire model. Because there were differing numbers of equations in each method, the number of parameters (k) including the intercept was counted for each method. From a statistical standpoint, the model with the lowest value of AIC or BIC is preferred as these criteria select a model with lowest RSS consistent with keeping the risk of including spurious correlations in the model at an acceptable level.

Results and Discussion

The purpose of this research was to evaluate alternative models of valuing a log so that its value would be as close as possible to the calculated gross value in dollars per cubic foot considering the amount of information provided by each model. As mentioned before, the gross value was estimated by using the quantities of lumber manufactured from a log and prices of all available lumber grades. The gross value estimated in equation (1) was the base with which the estimated values obtained in different methods were compared.

Tables 2 through 4 show the predictive equations for estimating the value of a log in the direct, intermediate, and detailed methods. The signs of the coefficients are along expected lines in most cases. The number of equations was reduced from a total of 61 in the detailed method to 28 in the intermediate method, and to 7 in the direct method. Note, however, that these equations were used to predict different things in each of these three models as explained in the "Data and Methods" section.

Table 5 provides a comparative summary of R^2 values from the three methods. Note that the R^2 values in the direct method are higher than the lowest R^2 values in the other two methods. The R^2 values were higher in the direct and intermediate methods than the highest R^2 values in the detailed method for all ponderosa pine data sets. The highest R^2 values in the detailed method were higher than the highest R^2 values in the direct and intermediate methods for the equations for other species.

The coefficient of variation (standard deviation as a percentage of the mean) provides a measure of variation in the estimated values in each particular method. The coefficient of variation in the estimated values of logs was highest in the intermediate method and lowest in the detailed method for all data sets except the Douglas-fir and western hemlock data sets (table 6). The coefficient of variation for actual gross values of log, however, was higher than those in all three methods.

The values of logs in direct, intermediate, and detailed methods were estimated by using equations (2), (4), and (6), respectively. Mean values and other statistics for the three different models for ponderosa pine, Douglas-fir, western hemlock, and true firs, for comparison, are shown in table 7. The estimated mean values of logs in the direct and intermediate methods were close, and the difference in value of logs between these two methods did not exceed \$0.02 per cubic foot. The difference between the direct and detailed methods ranged from \$0.12 to \$0.63 indicating a deviation of 4.56 to 21.95 percent from the actual value of logs. The detailed method underestimated the value of logs for three data sets (old- and young-growth Dimension ponderosa pine and Douglas-fir) and overestimated for the remaining four data sets.

As already mentioned, the gross calculated value and the value estimated by the direct method are equal by definition, and consequently the average deviation, which measures the average bias, from the calculated (observed) gross value was zero for the direct method. Between the two remaining methods, average deviation from the gross calculated value was less for the intermediate than for the detailed method for all the data sets.

Average absolute deviations, which measure the estimated accuracy, were about the same in the direct and intermediate methods for all data sets. Average absolute deviation was higher for the detailed method for all cases. Mean deviation squares were also higher for the detailed method than for the direct and intermediate methods for all data sets without exception.

Table 2—Estimated equations for the direct method

Tree species and lumber type	Intercept	Small-end diameter (D) (1)	Small-end diameter (D) (2)	Taper (T)	Length (H)	R^2	Number of observations
Ponderosa pine:							
Old growth, Dimension	2.19^a	$0.01(D^2)^a$	—	—	$-88.20^*(1/H^2)^c$	0.57	66
Old growth, Appearance	-3.15^a	$.51(D)^a$	$13.93(1/D)^a$	$-7.56(T^2)^a$	—	.63	266
Young growth, Dimension	1.97^a	$.008(D^2)^a$	—	$1.06(T)^c$	$-57.96(1/H^2)^a$	.46	278
Young growth, Appearance	-.45.	$32(D)^a$	$17.57(1/D^2)^c$	$-2.76(T)^a$	$.0017(H^2)^a$	.52	418
Douglas-fir, Dimension	2.24^a	$.11(D)^a$	$-.70(1/D)$	$-2.68(T)^a$	—	.23	1,517
Western hemlock, Dimension	2.60^a	$.04(D)^a$	—	$-2.14(T)^a$	$-33.65(1/H^2)^b$	.12	321
True firs, Dimension	4.76^a	$-21.11(1/D)^a$	$50.95(1/D^2)^a$	$-2.46(T)^a$	$-59.48(1/H^2)^a$	.29	1,663

— = variable not entered or retained in the step-wise regression; variables were selected by step-wise regression with significance level to enter = 0.15 and significance level to retain = 0.10; when more than one form of the same variable was selected in the step-wise regression, two forms of D, and one form for each of T and H with the highest partial R^2 were retained in the final estimated equations.

[a] Significance at 1-percent level.

[b] Significance at 5-percent level.

[c] Significance at 10-percent level.

The results indicate that the mean values of logs in the direct and intermediate methods are closer to the actual value. In the detailed method, the number of equations involved in the prediction was higher than in the intermediate method. The reason for the higher deviations in the detailed method is that it involved more equations with low R^2 values. Although the detailed method used fewer lumber grade groups, the intermediate method used more lumber grades with the corresponding prices.

The AIC and BIC values were highest for the detailed method in all cases and lowest for the direct method. Because of the higher number of equations and more estimated parameters involved in the estimation, the detailed method resulted in higher AIC and BIC values. This also resulted in higher average deviation and average absolute deviation from the actual gross values in the detailed method. Hence the detailed method does not give any better estimates than those given by the direct and intermediate methods. However, the value of the detailed method lies in the information about the quantity and quality of lumber grade groups it generated.

Given the above tests and comparisons, valuing a log can be simplified by the direct and intermediate methods by using fewer equations and incorporating more detailed lumber grade prices into the process of prediction than in the detailed method. The value of logs predicted by the direct and intermediate methods was closer to the calculated gross value than that predicted by the detailed method.

The direct method is the simplest method and is therefore desirable when estimates of the value of the log are all that are desired. When some information on the relative proportions of log value that are derived from lumber, chips, and residues is of interest, then the intermediate method offers a good alternative that is still computationally easy to derive. When specifics about the change in the proportions of grade groups with increasing log diameter are of interest, the detailed method is needed. The detailed method allows users to infer information about which grade groups increase and which decrease when the average lumber value changes. This is not always obvious from

Table 3—Estimated equations for the intermediate method

Tree species and lumber type recovery variables[d]	Intercept	Small-end diameter (D) (1)	Small-end diameter (D) (2)	Taper (T)	Length (H)	R^2	Number of observations
Ponderosa pine:							
Old growth, Dimension:							
LRF	10.85^a	$-28.31(1/D^2)^c$	—	$-5.77(T)^a$	$-261.66(1/H^2)^b$	0.28	66
R_{rp}	.10	$-.006(D)^c$	$0.0004(D^2)^a$	$-.17(T^2)$	$-1.80(1/H^2)^c$	.41	66
P_{bf}	$.48^a$	$-.05(D)^a$	$.004(D^2)^a$	—	$-6.78(1/H^2)$	.65	66
L_{rp}	$.83^a$	$-.88(1/D)^a$	—	$-.34(T)^b$	$-18.98(1/H^2)^b$	.33	66
Old growth, Appearance:							
LRF	12.56^a	$-74.79(1/D)^a$	$177.00(1/D^2)^a$	$-2.34(T)^b$	—	.42	266
R_{rp}	$.09^a$	$.0006(D)$	$-.18(1/D)^c$	$-.03(T)^b$	$.00007(H^2)^a$	.24	266
P_{bf}	$.32^a$	$.002(D^2)^a$	$2.46(1/D^2)^b$	$-.23(T)^a$	—	.48	266
L_{rp}	$.24^a$	$.04(D)^a$	$-.74(1/D^2)$	$-.22(T)^b$	—	.51	266
Young growth, Dimension:							
LRF	7.48^a	$.12(D)^a$	—	—	$-151.59(1/H^2)^a$	.13	178
R_{rp}	$.05^a$	$.00015(D^2)^a$	$.15(1/D^2)^c$	—	—	.21	178
P_{bf}	$.39^a$	$-.03(D)^a$	$.002(D^2)^a$	—	$-3.49(1/H^2)^b$	.52	178
L_{rp}	$.47^a$	$.01(D)^a$	—		$-9.42(1/H^2)^a$	.19	178
Young growth, Appearance:							
LRF	3.34^a	$.29(D)^a$	$-3.46(1/D^2)$	$-4.09(T)^a$	$.003(H^2)^a$	.33	418
R_{rp}	$.09^a$	$.0004(D)$	$-.15(1/D)$	$-.07(T^2)^a$	$.00005(H^2)^a$	.15	418
P_{bf}	$.32^a$	$.001(D^2)^a$	$-.16(T)^a$	—	$.0001(H^2)^b$	.44	418
L_{rp}	-.45	$.32(D)^a$	$17.57(1/D^2)^c$	$-2.76(T)^a$	$.002(H^2)^a$	.52	418
Douglas-fir, Dimension:							
LRF	5.10^a	$.29(D)^a$	—	$-4.29(T)^a$	—	.23	1,517
R_{rp}	$.06^a$	$.002(D)^a$	—	$-.04(T)^a$	—	.13	1,517
P_{bf}	$.40^a$	$.00001(D^2)$	$-.13(1/D)^b$	$-.45(T^2)^a$	—	.09	1,517
L_{rp}	$.36^a$	$.02(D)^a$	—	$-.32(T)^a$	—	.24	1,517
Western hemlock, Dimension:							
LRF	9.57^a	$-10.80(1/D)^a$	—	—	$-16.72(1/H)^a$	.10	321
R_{rp}	$.08^a$	$-.05(1/D)^c$	—	$-.07(T)^a$	$.16(1/H^2)$	.08	321
P_{bf}	$.38^a$	$-.23(T)^a$	—	$-.23(T)^a$	$-.00001(H^2)^a$	.24	321
L_{rp}	$.69^a$	$-.82(1/D)^a$	—	—	$-1.14(1/H)^a$	.10	321
True firs, Dimension:							
LRF	12.19^a	$-43.28(1/D)^a$	$100.41(1/D^2)^a$	$-6.36(T)^a$	$-167.27(1/H^2)^a$	.26	1,663
R_{rp}	$.07^a$	$.001(D)^a$	—	$-.06(T)^a$	$-.19(1/H)^a$	.18	1,663
P_{bf}	$.43^a$	$-1.06(1/D)^a$	$2.70(1/D^2)^a$	$-.07(T)^a$	$-2.06(1/H^2)^a$	.11	1,663
L_{rp}	$.61^a$	$.007(1/D)^b$	$-.69(1/D^2)^a$	$-.42(T)^a$	$-13.23(1/H^2)^a$	.22	1,663

— = variable not entered or retained in the step-wise regression; variables were selected by step-wise regression with significance level to enter = 0.15 and significance level to retain = 0.10; when more than one form of the same variable was selected in the step-wise regression, two forms of D, and one form for each of T and H with the highest partial R^2 were retained in the final estimated equations.

[a] Significance at 1-percent level.

[b] Significance at 5-percent level.

[c] Significance at 10-percent level

[d] LRF = lumber recovery factor, R_{rp} = recovery portion of residues, P_{bf} = price of lumber in dollars per board foot, L_{rp} = recovery portion of lumber.

Table 4—Estimated equations for the detailed method

Tree species and lumber grade	Intercept	Small-end diameter (D) (1)	Small-end diameter (D) (2)	Taper (T)	Length (H)	R^2	Number of observations
Ponderosa pine:							
Old growth, Dimension—							
No. 2 and better	-36.52	29.30(D)[c]	-1.58(D^2)[a]	—	-3387.0($1/H^2$)[b]	0.44	66
Utility	23.17[a]	-1.55(D)[a]	—	—	—	.12	66
Economy	-14.85[a]	—	—	—	4108.1($1/H^2$)[a]	.27	66
2 Commons and better	27.27[a]	-7.58(D)[a]	.49(D^2)[a]	—	—	.53	66
3 Commons	25.04[b]	-6.39(D)[b]	.43(D^2)[a]	—	—	.36	66
4 Commons	10.77[c]	81.01(1/D)[a]	—	—	-.95(H)[a]	.37	66
Chips	10.65[b]	—	—	97.84(T)[a]	2286.3($1/H^2$)[a]	.41	66
Residues	9.99[a]	-.65(D)[c]	.04(D^2)[a]	-16.56(T^2)[a]	-180.41($1/H^2$)[c]	.41	66
Lumber recovery factor	10.85[a]	-28.31($1/D^2$)[c]	—	-5.77(T)[a]	-261.66($1/H^2$)[b]	.28	66
Old growth, Appearance—							
Moulding and better	-6.54[b]	.06(D^2)[a]	293.24($1/D^2$)[a]	—	—	.08	266
No. 1 Shop	-.02	.02(D^2)[a]	—	—	—	.08	266
No. 2 Shop	11.68[a]	-3.12(D)[a]	.21(D^2)[a]	—	—	.43	266
No. 3 Shop	-27.04[a]	3.02(D)[a]	278.25(1/D)[c]	—	—	.30	266
2 Commons and better	59.33[a]	-.13(D^2)[a]	—	-85.00(T)[a]	—	.19	266
3 Commons	65.07[a]	-.14(D^2)[a]	-142.32(1/D)[c]	62.57(T)[a]	—	.11	266
4 Commons	7.29[a]	—	-.02(D^2)[b]	72.37(T^2)[a]	—	.05	266
5 Commons	.49	.01(D)	—	-	—	.00	266
Chips	68.69[a]	-3.81(D)[a]	—	46.17(T)[a]	—	.49	266
Residues	9.34[a]	.06(D)	-17.98(1/D)[c]	-3.33(T)[b]	.007(H^2)[a]	.24	266
Lumber recovery factor	12.56[a]	-74.79(1/D)[a]	177.00($1/D^2$)[a]	-2.34(T)[b]	—	.42	266
Young growth, Dimension—							
No. 2 and better	16.76	16.46(D)[a]	-.99(D^2)[a]	—	-2714.9($1/H^2$)[a]	.27	178
Utility	18.54[a]	-.05(D^2)[c]	—	—	—	.02	178
Economy	-15.69[a]	54.99(1/D)[a]	—	—	214.67(1/H)[a]	.11	178
2 Commons and better	15.88[a]	-4.85(D)[a]	.34(D^2)[a]	—	—	.43	178
3 Commons	12.53[b]	-3.83(D)[a]	.30(D^2)[a]	55.64(T^2)[b]	—	.42	178
4 Commons	-7.18[a]	31.71(1/D)[a]	—	14.73(T)[c]	1294.6($1/H^2$)[a]	.22	178
Chips	7.46	377.89(1/D)[a]	-1066.2($1/D^2$)[b]	218.71(T^2)[a]	—	.22	178
Residues	4.95[a]	.02(D^2)[a]	14.55($1/D^2$)[c]	—	—	.21	178
Lumber recovery factor	7.48[a]	.12(D)[a]	—	—	-151.59($1/H^2$)[a]	.13	178
Young growth, Appearance:							
Moulding and better	.59	.06(D)	—	—	—	.00	418
No. 1 Shop	-1.20[c]	—	—	3.20(T)[c]	.007(H^2)[b]	.02	418
No. 2 Shop	4.61	-1.53(D)[b]	0.12(D^2)[a]	14.18(T^2)[b]	—	.20	418
No. 3 Shop	-29.74[a]	.25(D^2)[a]	131.17(1/D)[a]	-9.99(T)[b]	—	.49	418
2 Commons and better	30.66[a]	-.099(D^2)[a]	—	-51.53(T)[a]	125.81(1/H)	.13	418
3 Commons	20.53	9.64(D)[a]	-0.56(D^2)[a]	36.76(T)[a]	-1658.1($1/H^2$)[a]	.08	418
4 Commons	-2.31	344.84($1/D^2$)[a]	—	17.38(T)[b]	1053.9($1/H^2$)[a]	.10	418
5 Commons	.26	-.02(D)	—	—	—	.00	418
Chips	66.14[a]	-3.81(D)[a]	—	63.47(T)[a]	—	.41	418
Residues	8.99[a]	.04(D)	-15.1(1/D)	-7.01(T^2)[a]	.005(H^2)[a]	.15	418
Lumber recovery factor	3.34[a]	.29(D)[a]	-3.46($1/D^2$)	-4.09(T)[a]	.003(H^2)[a]	.33	418

Table 4—Estimated equations for the detailed method (continued)

Tree species and lumber grade	Intercept	Small-end diameter (D) (1)	Small-end diameter (D) (2)	Taper (T)	Length (H)	R^2	Number of observations
Douglas-fir: Dimension—							
Select structural	31.04[a]	-6.24(D)[a]	.50(D^2)[a]	-69.44 (T)[a]	—	.25	1,517
No. 2 and better	-44.20[a]	.62(D^2)[a]	-69.69(1/D)		3.33(H)[a]	.63	1,517
No. 3 and Utility	-14.03[a]	.12(D^2)[a]	—	274.15(T^2)[a]	.02(H^2)[a]	.28	1,517
Economy	6.12[c]	-3.14(D)[a]	.22(D^2)[a]	127.94(T^2)[a]	.01(H^2)[a]	.20	1,517
Chips	58.55[a]	-2.31(D)[a]	—	35.70(T)[a]	—	.23	1,517
Residues	5.78[a]	.19(D)[a]	—	-3.81(T)[a]	—	.13	1,517
Lumber recovery factor	5.10[a]	.29(D)[a]	—	-4.29(T)[a]	—	.23	1,517
Western hemlock: Dimension—							
Select structural	-3.76	0.18(D^2)[a]	—	-50.74(T)[a]	.01(H^2)[a]	.31	321
No. 2 and better	-43.94[a]	.77(D^2)[a]	—	93.28(T)[b]	.07(H^2)[a]	.68	321
No. 3 and Utility	-55.10[a]	.33(D^2)[a]	—	200.1(T)[a]	.05(H^2)[a]	.66	321
Economy	-19.97[a]	.12(D^2)[a]	—	72.27(T)[a]	.014 (H^2)[a]	.43	321
Chips	26.30[a]	90.42(1/D)[a]	—	—	901.41(1/H^2)[a]	.09	321
Residues	9.17[a]	-5.68(1/D)[b]	—	-6.08(T)[a]	-.03(H)[a]	.10	321
Lumber recovery factor	9.57[a]	-10.80(1/D)[a]	—	—	-16.72(1/H)[a]	.10	321
True firs: Dimension—							
Select structural	6.44[a]	0.10(D^2)[a]	—		-130.16(1/H)[a]	.18	1,663
No. 2 and better	-66.37[a]	.56(D^2)[a]	216.34(1/D^2)[b]	-76.20(T^2)[a]	3.82(H)[a]	.67	1,663
No. 3 and Utility	-17.13[a]	.12(D^2)[a]	—	8.69(T)[b]	1.18(H)[a]	.24	1,663
Economy	-2.34[b]	.04(D^2)[a]	—	6.71(T)[b]	.02(H^2)[a]	.08	1,663
Chips	40.50[a]	-1.04(D)[a]	185.69(1/D^2)[a]	48.05(T)[a]	1448.71(1/H^2)[a]	.22	1,663
Residues	6.61[a]	.11(D)[a]	—	-5.59(T)[a]	-18.74(1/H)[a]	.18	1,663
Lumber recovery factor	12.19[a]	-43.28(1/D)[a]	100.41(1/D^2)[a]	-6.36(T)[a]	-167.27(1/H^2)[a]	.26	1,663

— = variable not entered/retained in the step-wise regression; variables were selected by step-wise regression with significance level to enter = 0.15 and significance level to retain = 0.10; when more than one form of the same variable were selected in the step-wise regression, two forms of D, and one form for each of T and H with the highest partial R^2 were retained in the final estimated equations.

[a] Significance at 1-percent level.

[b] Significance at 5-percent level.

[c] Significance at 10-percent level

Table 5—Summary of R^2 values for estimated equations in the different methods

Tree species and lumber type	Direct method R^2	Intermediate method R^2 Lowest	Intermediate method R^2 Highest	Detailed method R^2 Lowest	Detailed method R^2 Highest
Ponderosa pine:					
Old growth, Dimension	0.57	0.28	0.65	0.12	0.53
Old growth, Appearance	.63	.24	.51	.00	.49
Young growth, Dimension	.46	.13	.52	.02	.43
Young growth, Appearance	.52	.15	.52	.00	.49
Douglas-fir: Dimension	.23	.09	.24	.13	.63
Western hemlock: Dimension	.12	.08	.24	.09	.68
True firs: Dimension	.29	.11	.26	.08	.67

Table 6—Coefficient of variation of values of logs in the different methods[a]

Tree species and lumber type	Gross value	Direct method	Intermediate method	Detailed method
Ponderosa pine:				
Old growth, Dimension	33.97	25.63	29.34	19.13
Old growth, Appearance	47.63	37.75	38.67	29.57
Young growth, Dimension	33.49	22.67	23.90	20.14
Young growth, Appearance	41.80	30.19	30.44	21.87
Douglas-fir: Dimension	28.43	14.48	14.23	17.70
Western hemlock: Dimension	25.04	8.56	8.11	8.57
True firs: Dimension	33.50	17.99	18.39	13.06

[a] Coefficient of variation = (standard deviation/mean) × 100.

Table 7—Comparison of mean values of log under different methods

Item	Direct method	Intermediate method	Detailed method
Ponderosa pine:			
Old growth, Dimension—			
Mean	3.13	3.12	2.90
Average deviation	.00	.01	.23
Average absolute deviation	.54	.53	.56
Average deviation squares	.48	.46	.61
Number of lumber grades	48	48	6
Number of regression equations	1	4	9
Number of parameters	3	17	29
AIC[a]	-.23	.18	.66
BIC[b]	-.24	.13	.58
Ponderosa pine:			
Old growth, Appearance—			
Mean	3.44	3.44	3.63
Average deviation	.00	-.01	-.19
Average absolute deviation	.72	.72	.80
Average deviation squares	.99	1.00	1.16
Number of lumber grades	48	48	8
Number of regression equations	1	4	11
Number of parameters	4	17	35
AIC[a]	.03	.13	.33
BIC[b]	.03	.15	.38
Ponderosa pine:			
Young growth, Dimension—			
Mean	2.56	2.55	2.29
Average deviation	.00	.00	.27
Average absolute deviation	.50	.50	.55
Average deviation squares	.40	.40	.48
Number of lumber grades	48	48	6
Number of regression equations	1	4	9
Number of parameters	4	13	30
AIC[a]	-.36	-.26	.02
BIC[b]	-.35	-.24	.06

Table 7—Comparison of mean values of log under different methods (continued)

Item	Direct method	Intermediate method	Detailed method
Ponderosa pine:			
Young growth, Appearance—			
Mean	2.64	2.62	2.85
Average deviation	.00	.02	-.21
Average absolute deviation	.57	.58	.64
Average deviation squares	.58	.593	.66
Number of lumber grades	48	48	8
Number of regression equations	1	4	10
Number of parameters	5	19	39
AIC[a]	-.21	-.14	.01
BIC[b]	-.20	-.11	.07
Douglas-fir, Dimension—			
Mean	2.87	2.85	2.23
Average deviation	.00	.02	.63
Average absolute deviation	.57	.57	.80
Average deviation squares	.57	.57	.98
Number of lumber grades	16	16	4
Number of regression equations	1	4	7
Number of parameters	4	13	27
AIC[a]	-.24	-.23	.03
BIC[b]	-.24	-.22	.05
Western hemlock, Dimension—			
Mean	2.63	2.62	2.75
Average deviation	.00	.01	-.12
Average absolute deviation	.46	.46	.49
Number of lumber grades	16	16	4
Average deviation squares	.39	.39	.44
Number of regression equations	1	4	7
Number of parameters	4	14	26
AIC[a]	-.38	-.32	-.19
BIC[b]	-.37	-.30	-.15
True firs, Dimension—			
Mean	2.42	2.40	2.57
Average deviation	.00	.02	-.16
Average absolute deviation	.54	.54	.56
Average deviation squares	.48	.48	.52
Number of lumber grades	16	16	4
Number of regression equations	1	4	6
Number of parameters	5	19	27
AIC[a]	-.31	-.30	-.25
BIC[b]	-.31	-.28	-.23

[a] AIC = Akaike Information Criterion.

[b] BIC = Bayesian Information Criterion.

the average, and understanding how the proportion of lumber grade groups change in relation to each other is sometimes important in understanding the effects of forest management on resource value.

Our results show that the mean values per cubic foot of log were close in the direct and intermediate methods but diverged in the detailed method from the actual value by either overestimating or underestimating the value of logs. This suggests that users can select the least complex computational method that gives them the desired information and feel confident that the value of log estimated by using either of the other methods would be relatively close.

These methods reflect the tradeoff between simplicity and the amount of information developed. The detailed method provides extensive information on the volumes of different lumber grades as well as a means to do a complete analysis of forest management activities; the other two methods do not. If users wish to make a simple calculation of value of a forest stand based on the small-end diameter and taper of logs, the direct method would suffice. If more detailed information is needed, such as an estimate of the value of a forest stand based on the LRF, recovery proportions of chips and residues, and price in dollars per board foot, the intermediate method would give the most accurate estimate. Although the detailed method enables us to get more information pertaining to recovery of lumber in different grade groups, it does not enable us to get a better estimate of log value than the direct and intermediate methods as it tends to overestimate or underestimate the values.

Conclusions

In this study, three alternative approaches for predicting the value of a log were examined. Taking the calculated gross value of logs obtained by applying all detailed grades and available prices as the base method, the estimated value of logs in three models—direct, intermediate, and detailed—were compared with the calculated gross value of logs. The average deviations, average absolute deviations, average deviation squares, and model selection criteria showed that the direct and intermediate models produced predictive values of logs closer to the calculated gross value for most samples. Direct and intermediate models also have the advantage of relying on fewer predictive equations and more detailed grades and prices than does the detailed method. Although the detailed model uses fewer lumber grade groups and respective prices, it enables us to derive extensive information on the values and volumes of lumber products from a forest. The detailed model, however, produced values that deviated more from the calculated gross value than did the other two models. Depending on the need for detailed information, any of these models can be used in valuing logs in a forest stand. The simplest one is the direct model in that it gives only the value of the forest stand quickly and the detailed model is more sophisticated because it gives an array of detailed information. Although the estimated value in the intermediate model is closer to the calculated gross value, it enables us to get limited information on proportions of lumber, chips, and residues.

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Metric Equivalents

When you know	Multiply by	To get:
Inches	2.540	Centimeters
Feet	0.305	Meters

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