United States
Department of
Agriculture

Forest Service

**Northeastern Forest
Experiment Station**

Research Paper NE-657

Timber Sale Value as a Function of Sale Characteristics and Number of Bidders

Paul E. Sendak

Abstract

Examines the effect of sale characteristics and number of bidders on sale value for timber sold by sealed-bid auction on the Green Mountain National Forest in Vermont. As anticipated from theory and previous empirical studies, increasing the number of bidders tended to increase the winning-bid value for the timber auctions studied. Tobit analysis was used because of the high number of timber sale offerings that received no bids. Efforts made to ensure that an offering received at least one qualified bid had a greater impact on sales revenue than efforts made to increase the high-bid value. In designing sales, managers should avoid setting appraisal value too high in relation to timber quality or should seek methods other than timber sales to regenerate poor quality stands.

The Author

PAUL E. SENDAK, forest economist, is Project Leader of the research unit on the economic potential of forest production in the North at the Northeastern Forest Experiment Station, Burlington, Vermont. He received a B.S. degree in forestry from Rutgers University, and an M.S. degree in forestry and Ph.D. degree in forest economics from the University of Massachusetts. He joined the U.S. Department of Agriculture, Forest Service in 1969.

Acknowledgment

This research resulted from a Cooperative Research Agreement between the U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station and the University of Montana, School of Forestry. I am indebted to Professor David H. Jackson's valuable contributions to the study design, data analysis, and final report. Any inaccuracies or errors that remain are the responsibility of the author. I am indebted also to the Green Mountain National Forest staff—in particular, Wayne Kingsley and Ginger Marx—for guidance through the timber sales records and sale procedures.

Manuscript received for publication 11 July 1991

Northeastern Forest Experiment Station
5 Radnor Corporate Center
100 Matsonford Road, Suite 200
P.O. Box 6775
Radnor, Pennsylvania 19087-4585

December 1991

Introduction

Federal timber auctions have been the subject of several empirical studies. This study focuses on timber auctions in the Green Mountain National Forest (NF) in Vermont and the influence that sale characteristics and number of bids submitted have on the winning-bid value. The study has implications for timber auction design in promoting competition and increasing revenues. The Green Mountain NF frequently has offered timber sales that received no bids. Thirty-two percent of the timber stands on the Green Mountain NF are of poor quality. These stands frequently are prescribed for regeneration cuts to convert them to higher quality. As a result, many of the timber sales in this study had a high percentage of poorer quality stands.

According to Riley and Samuelson (1981), "the auction model is a useful description of 'thin markets' characterized by a fundamental asymmetry of market position." Typically, one seller faces a finite, and usually very small, number of potential bidders, whose valuation of the product is unknown to the seller. The auction follows an explicit set of rules, typically set by the seller, which includes how bids are to be submitted and how the winning bid is selected.

The auctions for Green Mountain NF timber are first-price, sealed-bid auctions with a reservation price set by the seller. Sealed bids are submitted to the seller and the highest bid wins, with the winner paying the amount bid. The seller's reservation price sets a floor that all qualified bids must equal or exceed.

It was hypothesized that a positive relationship exists between the number of bids submitted on a timber sale and the winning bid. Tobit analysis was used to estimate two models that predict the winning-bid value because the dependent variable was censored (Maddala 1983). The second of the two models included a transformation of the number of bids submitted as an explanatory variable. The number-of-bids coefficient was statistically significant. Results are discussed in relation to the wood-using industry in Vermont and in reference to the objectives of timber sales on the Green Mountain NF.

Timber Auction Studies

A number of survey articles on auctions have been published and, rather than attempt an exhaustive review here, interested readers are referred to them. McAfee and McMillan (1987) survey the recent literature on auctions and bidding. Earlier literature is surveyed by Engelbrect-Wiggans (1980), and Stark and Rothkopf (1979) provide a comprehensive bibliography on competitive bidding. The literature on studies of federal timber auctions and the effect of number of bidders on winning-bid value is reviewed here in more detail.

Auction theory predicts that winning-bid value tends to increase with increases in the number of bidders (McAffee and McMillan 1987, Engelbrect-Wiggans 1980). Several studies are concerned with examining the number of bidders participating in an auction. Mead (1966) concluded that auctions with few bidders occurred because of the structure of the wood-using industries. There are few potential buyers because markets are constrained in area by the high cost of hauling logs from woods to mill. This, coupled with an assumption that local timber supplies are relatively inelastic, led Mead to conclude that collusion among buyers of Douglas-fir timber is common.

In a study of oral versus sealed bidding for Forest Service timber, Johnson (1979) found a positive relationship between the number of bidders and the winning-bid value. Number of bidders was one independent variable in a multiple regression model to predict winning-bid value, as estimated by ordinary least squares (OLS).

Hansen (1986) also investigated oral versus sealed bidding for national forest timber. He estimated three high-bid models using least squares and maximum likelihood techniques in which the number of qualified bidders appeared in each model as a predictor variable. In all three cases, the number-of-bidders coefficient was statistically significant and positive. Brannman et al. (1987) tested theoretical predictions about the effects of number of bidders on winning-bid value in five auction settings, among them federal timber sales. They found that winning bid increases with the number of bidders.

Buongiorno and Young (1984) modeled winning bid using OLS conditional on sales that received at least two bids. They recognized the potential for unsold offerings and that OLS regression would not be an adequate method when no bids were received. Huang and Buongiorno (1986), realizing the potential bias in ignoring unsold timber auctions, used Tobit regression. Number of bids is not a variable in their winning-bid model, although Tobit regression can be used to model the probability that an offering will sell (receive at least one bid) based on the other independent variables, will determine the appraisal value that will ensure a certain probability of sale, and will describe the demand schedule for timber on the forest of interest.

Jackson and Gould (1987)[1] and Niccolucci (1989) modeled the number of bids using limited-dependent-variable techniques. Niccolucci used discriminant analysis and logit regression to discriminate between sold and unsold offerings. Jackson and Gould (1987) used logit regression to model the probability of single-bid auctions versus multiple-bid sales. They predicted winning-bid value using OLS. The market they investigated had no unsold offerings but many single sealed-bid sales.

Setting a reserve price is a good strategy for the seller

[1]Jackson, D.H.; Gould, E.M. 1987. Contractual arrangements, the level of competition, and value of national forest timber. Mimeo. 16 p.

because theory shows that, on average, it will result in higher winning bids (McAfee and McMillan 1987). Riley and Samuelson (1981) show that for a broad family of auction rules, expected seller revenue is maximized if the seller announces an appropriately chosen reserve price.

Methods

Procedure for Green Mountain NF Timber Sales

The Green Mountain NF advertises each sale in local newspapers and in a prospectus and solicits sealed bids from a list of approximately 80 potential bidders. A showing is scheduled for interested bidders to view the timber offered for sale. The winning bid must match or exceed the seller's appraisal value or reserve price. If no sealed bid is received, a purchaser can negotiate with the Forest Service, essentially match the appraisal value, and be awarded the sale.

The sales in the sample population are lump-sum sales. The trees are marked for cutting before the sale and the timber volumes are estimated. Timber payments are not dependent upon the measurement of logs removed but, rather, on presale volume estimates. Lump-sum sales encourage the use of low-quality timber.

Roads that are to become a part of the permanent road system, thus representing a capital investment in infrastructure, are often financed through purchaser credit in the National Forest System. Instead of paying the timber purchaser in cash for road construction, the Forest Service grants credit against the purchaser's timber payment account for building the roads. The credit is earned as the road is built. However, purchaser credits do not appear to be a significant factor on the Green Mountain NF. Few new roads are planned and since virtually all potential bidders are classified as "small business," bidders can have the Forest Service contract directly for permanent road construction.

Transactions-evidence appraisal is used by the Green Mountain NF. Timber is advertised at the appraisal value, which is 85 percent of the average price of previous sales over the past 12 months. A sale may be appraised above or below the 85 percent standard if justified by sale attributes that deviate from the norm. But the advertised appraisal value cannot be lower than the base rate set by law. Three sale attributes used in adjusting the appraisal value are: percentage of pulpwood in the sale, slope, and yarding distance. Low quality timber is converted into wood pulp and high quality timber is converted into lumber, veneer, and specialty products. The Green Mountain Forest Plan recognizes the need to subsidize removal of poor quality timber with high quality timber in order to make sales more attractive to bidders (USDA For. Serv. 1985).

Sample Data

The sample population consisted of all sales on the Green Mountain NF with active harvesting operations during the first quarter of 1988. There were 45 sales with active harvesting operations sold at auction over the previous 10 years, but most of these sales (80 percent) had been awarded over the previous 4 years. In addition, data were gathered on 19 offerings advertised during the 10-year period, but received no bids. Thus, the total sample of auctions was 64.

The population of timber sale offerings may be divided into three groups: 1, offerings that received at least one qualified bid; 2, offerings that received no qualified bids but were later sold by negotiation; and 3, offerings that received no bids and were not sold by negotiation. For this study, the last two groups were combined into no-bid auctions because the focus is on auctions, and group 2 was clearly not sold at auction. Simply put, offerings in group 1 were sold at auction; offerings in groups 2 and 3 were not. Group 2 contained eight offerings.

Five of the sixty-four sales sampled were advertised at the base rate. That is, the appraisal value for these sales was equal to, or less than, the legally mandated base rate. These five sales were relatively small in terms of timber volume and three received one bid while two received no bids. Two-thirds of the sales had at least one species of sawtimber or pulpwood advertised at the base rate. Most often, pulpwood was advertised at this rate, reflecting the poor market situation. But, most sales in the sample were advertised at an aggregate value significantly greater than would have resulted from applying the base rate.

Information describing the characteristics of the sales was obtained from timber sale records maintained at the Forest Supervisor's office and, in some cases, Forest District offices. Data were gathered on the winning-bid value and 21 potential explanatory variables. All dollar values were converted to constant 1982 value by the Gross National Product Implicit Price Deflator. All timber volumes were recorded in cubic feet to facilitate the comparison of sawlog and pulpwood volumes.

Statistical Procedure

Initial selection of explanatory variables for inclusion in a regression analysis was made using the pair-wise simple correlation coefficients among variables. Explanatory variables that had a statistically significant r value ($p \leq 0.05$) when paired with the dependent variable were retained; others were eliminated from further analysis. Since many of the variables measured the same characteristics but in different units, such as total number of trees and total acres cut as measures of sale size, there was a problem of near collinearity between some explanatory variables. Backward deletion was used to eliminate redundant variables from the regression model based on a combination of their t values and the pair-wise correlations between explanatory variables.

The Vermont timber market does not correlate well with national market indexes, such as lumber and pulp and paper production or lumber producer-price indexes. However, Vermont does publish a quarterly stumpage price report on regional prices, which gives a good measure of local timber market conditions. The value per cunit (VALUE) was calculated for each sale using the regional average stumpage prices for each species in the sale, weighted by the proportion of volume of that species relative to the total volume of the sale. For any species missing in the reports and for the few sales that occurred before the publication of Vermont stumpage prices, similar reports for northeastern New York counties were used.

The winning-bid model was specified as a Tobit regression because the dependent variable, real-winning bid, is censored (Maddala 1983). That is, the winning bid (WIN) is observed for offerings that received bids equal to or greater than the advertised appraisal value (ADV). For offerings that received no bids, no winning bid is observed. The lower truncation point was the advertised appraisal value so it varied with sale. The model is defined in the following way:

$$WIN_i = X_i\beta + u_i \quad \text{if } (-ADV_i + X_i\beta + u_i) \geq 0 \qquad (1)$$

$$= 0 \quad \text{if } (-ADV_i + X_i\beta + u_i) < 0 \qquad (2)$$

$$i = 1, 2, \ldots, N,$$

where WIN_i is the dependent variable, X_i is a vector of explanatory variables, β is a vector of unknown coefficients, and N is the number of observations. The error term, u_i, is assumed to be independently normally distributed with zero mean and constant variance, σ^2. In equation (2), the winning bid is arbitrarily assigned a value of zero when the value of $(X_i\beta + u_i)$ is less than the ADV_i.

Results

Table 1 lists and defines the variables used in the study and gives their means and standard deviations by sales which received at least one-bid and no-bid offerings. The dependent variable, winning bid/100 ft^3 (cunit), is a volume-weighted average price and is the bid per unit volume on each timber species times the Forest Service estimate of the respective volume summed over all species and divided by the total volume in the sale. High-valued species tend to increase the bid per cunit, while low-valued species tend to reduce the bid. Independent variables used in the analyses reflect timber quality, timber sale characteristics, and market conditions. Some of the variables are independent of managerial decisions, such as timing of timber sales to coincide with favorable markets. Other variables represent managerial choices in the design of timber sales, such as proportions of sawtimber and pulpwood, timber species, and trees chosen for harvest.

Winning-Bid Value

Two winning-bid models were estimated (Table 2). Model 1 is similar to the Huang and Buongiorno (1986) approach to predicting the high bid. Sale characteristics and a market variable were specified in Model 1. Model 2 differs from Model 1 in that the transformed number of bids [1/(1+NOBID)] was added to the list of explanatory variables (Table 2).

In Model 1, the likelihood ratio index (LRI), analogous to R^2 in ordinary regression analysis, was 0.22 and statistically significant ($p \leq 0.01$). Three of the four explanatory variables were significant, but all coefficients had the expected sign. All significance tests for the estimated coefficients were based on a one-tailed test because of *a priori* expectations of signs. The three significant coefficients: HIVAL—percentage of total sawlog volume in high-valued species, HAUL—average timber hauling distance, and VALUE—sale value based on average regional prices, were positive for HIVAL and VALUE and negative for HAUL. The coefficient for DBH, average diameter of trees in the sale, was positive as expected, but not significant.

HIVAL measured the relative quantity of high-valued species—the oaks, particularly northern red oak, white ash, and white pine—included in a sale. This variable

Table 1.—Definition of variables, sample means, and standard deviations for timber sales with one or more bids (n=45) and no-bid offerings (n=19)

Variable	Description	Sales with one or more bids		No-bid offerings	
		Sample mean	Standard deviation	Sample mean	Standard deviation
ADV	Advertised appraisal value per cunit (1982 $)	11.16	8.31	8.27	8.23
WIN	Winning bid per cunit (1982 $)	18.59	15.64	0	0
NOBID	Number of bids submitted	1.98	1.42	0	0
INVBID	Inverse of (1+NOBID)	0.39	0.13	1	0
DBH	Average diameter of trees in sale (inches)	11.07	1.27	10.26	1.15
HIVAL	Percentage of sawlog volume in high valued species (red oak, white oak, white ash, white pine)	2.96	5.90	1.74	1.43
HAUL	Average timber hauling distance (miles)	42.65	13.78	49.47	14.82
VALUE	Sale value per cunit based on prevailing average stumpage prices (1982 $)	20.42	7.26	16.59	6.66

Table 2.—Estimated winning-bid models, without, and with, the number of bids as an explanatory variable

Variable	Model 1			Model 2		
	Estimated coefficient	Standard error	t-statistic	Estimated coefficient	Standard error	t-statistic
INVBID	—	—	—	−30.72	6.26	−4.91***
DBH	1.18	0.95	1.25	−0.65	0.84	−0.77
HIVAL	1.16	0.19	6.19***	1.06	0.15	7.13***
HAUL	−0.18	0.08	−2.30**	−0.12	0.07	−1.74*
VALUE	1.22	0.18	6.94***	1.11	0.15	7.41***
Constant	−17.80	10.84	−1.64	16.83	11.03	1.53
S	6.75	0.74	9.09***	5.16	0.54	9.48***
	Log-likelihood = −160.16			Log-likelihood = −135.93		

*$p \leq 0.05$
**$p \leq 0.025$
***$p \leq 0.01$

appeared especially critical because a typical sale included large volumes of sugar maple, yellow birch, and red spruce sawtimber. The estimated coefficient was highly significant.

The estimated coefficient for VALUE was also highly significant. As expected, local timber-stumpage market conditions at the time of timber offering have a positive and measurable effect on the winning-bid value. The estimated coefficient for HAUL was negative because it represents a cost to the logger. The more distant the haul to market, the less valuable the timber, all else equal.

In Model 2, INVBID, the transformed number of bids, was added as an explanatory variable to the four original variables. The addition of this variable to Model 1 had the potential to cause the problem of simultaneity bias. That is, the number of bidders may be thought of as having been influenced by some of the explanatory variables that determine winning-bid value. This confounds the interpretation of the beta coefficients. However, as the following analysis shows, the problem was not serious in this case.

From Model 1 to Model 2 LRI increased from 0.22 to 0.34 and the estimated coefficient for INVBID is significant ($p \leq 0.01$). For the three significant variables in Model 1, the coefficients estimated in Model 2 were within two standard errors of the coefficients estimated in Model 1. The signs and significance of the coefficients were unchanged for HIVAL, VALUE, and HAUL. The coefficient for DBH was unexpectedly negative in sign, but still not significant. The addition of information about number of bids in Model 2 gives information not contained in the four variables in Model 1 and offers significant evidence of a positive relationship between number of bids and winning-bid value.

Decomposition of Tobit Coefficients

Tobit analysis can be used to determine both change in the probability that an offering will receive at least one bid (a bid that matches or exceeds the appraisal value), and the change in the winning-bid value if at least one bid is received. Thus, change in winning-bid value resulting from change in an explanatory variable may be decomposed into the marginal change in winning-bid value for offerings sold, and the change in probability that the offering will be sold (McDonald and Moffitt 1980).

Decomposition of the Tobit coefficients, as presented by McDonald and Moffitt (1980) and applied to forestry examples by Huang and Buongiorno (1986) and Dennis (1989), provides additional information. Table 3 shows the results of the decomposition of Model 1, using the average values of the predictor variables:

$$\text{WIN} = -17.80 + 1.18\ \text{DBH} + 1.16\ \text{HIVAL} - 0.18\ \text{HAUL} + 1.22\ \text{VALUE}$$

The coefficients of Model 2 were not decomposed because the number of bids was beyond direct control.

In particular, section 1, Table 3, shows the estimate of expected high-bid value over all observations (unconditional), E(Y); section 2 the expected value conditional on being above the limit, E(Y*); and section 3 the probability of being above the limit, F(Z), where F(·) is the cumulative normal distribution function and $Z = ((-ADV_i + X_iB)/\sigma)$. Section 4 shows adjustments to the Tobit beta coefficients needed to calculate the change in (a) E(Y), (b) F(Z), and (c) E(Y*) due to a change in the variable X_k. This obviously is conditional on the values of the X variables, so will change for any specific observation or combination of X values. The equations used to calculate the table entries are shown in the appendix.

The change in sale revenue due to an increase in high-bid value is the product of the change in high-bid value of those auctions above the limit and the probability of being above the limit, section 5, Table 3. And, the change in sale revenue due to an increase in the probability of receiving at least one bid is the product of the change in probability of being above the limit and the expected

Table 3.—Decomposition of Model 1 results using the total sample means

Section	Parameter estimated	Evaluated at mean for sample z=0.47
1	Expected high-bid value (WIN) (1982 $/cunit) E(Y)	11.60
2	Expected high-bid value conditional on ≥ ADV (1982 $/cunit) $E(Y^*)$	17.05
3	Probability of receiving at least one qualifying bid F(Z)	0.68
4	Changes due to a change in variable X_k	
(a)	$\partial E(Y)/\partial X_k$	$1.22B_k$
(b)	$\partial F(Z)/\partial X_k$	$0.05B_k$
(c)	$\partial E(Y^*)/\partial X_k$	$0.47B_k$
5	Change in the expected high bid due to increase in high-bid value (1982 $/cunit) $F(Z)\partial E(Y^*)/\partial X_k$	$0.32B_k$
6	Change in the expected high bid due to increase in probability of receiving at least one bid (1982 $/cunit) $E(Y^*)\partial F(Z)/\partial X_k$	$0.90B_k$

value of high bid if above the limit, section 6, Table 3. At the overall sample means, 26 percent [(0.32/1.22)X100] of the change in sale revenue is due to the increase in high-bid value and 74 percent [(0.90/1.22)X100] to the change in the number of auctions receiving at least one bid. Thus, efforts resulting in fewer no-bid auctions potentially have a greater positive impact on sale revenue than efforts resulting in higher bid values for sales that received bids.

In summary, the relationship between number of bids and winning-bid value is ignored in Model 1. Model 2 includes the transformed number of bids, 1/(1+NOBID). The number of bids significantly alters the model. The LRI increases from 0.22 to 0.34. The winning bid increases at a decreasing rate with the number of bids submitted.

Discussion

Auction theory predicts that seller revenue tends to increase with an increase in the number of bidders. Several empirical studies found evidence to support the prediction and this was found to be the case with federal timber sales on the Green Mountain NF in Vermont.

The number-of-bidders variable is interesting because, like the winning-bid variable, it can be considered an indicator of the quality of the timber sale. Therefore, the number-of-bidders variable should be a function of some of the same timber sale characteristics as the winning-bid value. This interpretation is presented by Schuster and Niccolucci (1990). However, in this study, the number-of-bidders variable works as an explanatory variable. It may be an indicator of otherwise unmeasured market conditions at the time of sale or it may proxy for important sale characteristics missing from among the variables being used to describe the sales.

The problem with Model 2, which includes the number-of-bidders variable, is that it cannot be used as a predictive model because number of bids is unknown until the timber auction. Schuster and Niccolucci (1990) avoided the problem by the use of instrumental variables and two-stage least squares. The procedure predicts the number of bids and this prediction can be used to estimate timber sale value and to avoid the potential simultaneity bias.

A significant number of timber sale offerings on the Green Mountain NF received no bids. Also timber management policy on the NF has forced many recent sale offerings to include poorer quality stands. These two conditions imply that the seller's appraisal value is being set too high on some offerings. As Huang and Buongiorno (1986) noted, an increase in the reservation price acts in opposing directions—it increases the conditional high bid but decreases the probability of selling.

To be sure, a small number of no-bid offerings can be an indication that appraisal value is not being set too low. Setting an appraisal value is a management decision that should consider the cost of reoffering the sale, including the postponement of revenue, as well as the cost of protecting the public's interest in the timber.

Mead's (1966) observation—that collusion among buyers of Douglas-fir timber both avoids competition and results in few bids on sales—does not seem a likely explanation here. Quite simply, sales that are unattractive in terms of timber quality or value tend to attract few, and sometimes no, bids. This is weakly supported in Table 1 that compares the sale characteristic means of sales and no-bid offerings. All differences between the means of the five sale characteristics had the *a priori* expected sign, but only one of the five was statistically significant ($p \leq 0.05$, one-tailed test). A probability value of 0.05/5=0.01 was used to protect against the five sales-characteristics hypotheses and to ensure that the overall Type-I error rate was no larger than approximately 0.05. Only the difference between the means of average diameter of trees in sale (DBH) was statistically different from zero.

There are major differences between western and eastern national forests. Among the most important are the smaller size, the lesser significance of timber production compared to other forest values, and the larger proportion of hardwoods in the East versus the West. The Green Mountain NF represents approximately 5 percent of the timber land area and 5 percent of the timber harvest in Vermont. With privately owned timber abundantly available in Vermont, the Green Mountain NF holds little monopoly power in selling timber.

Vermont's saw and veneer mill industry consists of several hundred mills. In contrast to markets for sawlogs, pulpwood markets are characterized by a few distant purchasers. Depending on species, pulpwood cut on the Green Mountain NF is trucked to one of three mills in New York State, in some instances over 100 miles away. While there may be substantial returns to searching the market for the best sawlog prices, there are few options for marketing pulpwood.

A large number of no-bid offerings is probably the result of an unacceptably high appraisal value relative to the quality of timber offered for sale. If the goals of management are being met by this process and the added cost of sales administration is acceptable, no change is recommended. However, poor quality stands could be cleared by low-bid contractors. Any merchantable timber could be sold at the landing to a high bidder, or included with an adjacent active sale. Other offerings might then be improved by the continued subsidizing of remaining lower quality timber by higher quality timber. By increasing the proportion of sawlogs, average diameter (DBH) and value (VALUE) will tend to increase and average haul distance (HAUL) will tend to decrease, because sawlog markets are much closer than pulpwood markets. Where possible, the species mix could also be improved, thus increasing the percentage of total sawlog volume in high-valued species (HIVAL) and also making the offering more attractive to potential bidders.

Literature Cited

Brannman, L.; Klein, J. D.; L. W. Weiss. 1987. **The price effects of increased competition in auction markets.** Review of Economic Statistics. 69(1):24-32.

Buongiorno, J.; Young, T. 1984. **Statistical appraisal of timber with an application to the Chequamegon National Forest.** Northern Journal of Applied Forestry. 1:72-76.

Dennis, D. F. 1989. **An economic analysis of harvest behavior: integrating forest and ownership characteristics.** Forest Science. 35(4):1088-1104.

Engelbrect-Wiggans, R. 1980. **Auctions and bidding models: a survey.** Management Science. 26(2):119-142.

Hansen, R. G. 1986. **Sealed-bid versus open auctions: the evidence.** Economic Inquiry. Vol. 24.

Huang, Mey F.; Buongiorno, J. 1986. **Market value of timber when some offerings are not sold: implications for appraisal and demand analysis.** Forest Science. 32(4):845-854.

Johnson, R. M. 1979. **Oral auction versus sealed-bids: an empirical investigation.** Natural Resources Journal. 19(April):315-336.

Maddala, G. S. 1983. **Limited-dependent and qualitative variables in econometrics.** Cambridge University Press. 401 p.

McAfee, R. P.; McMillan, J. 1987. **Auctions and bidding.** Journal of Economic Literature. 25:699-738.

McDonald, J. F.; Moffitt, R. A. 1980. **The uses of Tobit analysis.** Review of Economic Statistics. 62(2):318-321.

Mead, Walter J. 1966. **Competition and oligopsony in the Douglas-fir industry.** Berkeley, CA: University of California, 276 p.

Niccolucci, M. J. 1989. **A quantitative analysis of sold and unsold timber offerings in Region 1.** Missoula, MT: University of Montana. 51 p. M.S. thesis.

Riley, J. G.; Samuelson, W. F. 1981. **Optimal auctions.** American Economic Review. (June):381-392.

Schuster, E. G.; Niccolucci, M. J. 1990. **Comparative accuracy of six timber appraisal methods.** The Appraisal Journal. 58(1):96-108.

Stark, R.; Rothkopf, M. H. 1979. **Competitive bidding: a comprehensive bibliography.** Operations Research. 27(2):364-391.

U.S. Department of Agriculture, Forest Service. 1985. **Draft environmental impact statement—land and resource management plan.** Rutland, VT: U.S. Department of Agriculture, Forest Service, Eastern Region, Green Mountain National Forest. 532 p.

Appendix

Following are the equations for calculating the values in Table 3. Derivations can be found in McDonald and Moffitt (1980).

Sec. 1 $E(Y)=XBF(Z)+\sigma f(Z)$

Sec. 2 $E(Y^{*})=XB+\sigma f(Z)/F(Z)$

Sec. 4(a) $\partial E(Y)/\partial X_k=F(Z)\partial E(Y^{*})/\partial X_k+E(Y^{*})\partial F(Z)/\partial X_k$

Sec. 4(b) $\partial F(Z)/\partial X_k=f(Z)B_k/\sigma$

Sec. 4(c) $\partial E(Y^{*})/\partial X_k=B_k[1-Zf(Z)/F(Z)-f(Z)^2/F(Z)^2]$

Where $Z=(XB-L)/\sigma$, L is the lower truncation point in the Tobit analysis (ADV), $f(\cdot)$ is the unit normal density, and $F(\cdot)$ is the cumulative normal distribution function. Individual subscripts have been omitted to simplify the notation.

For computational purposes, estimates of β and σ were obtained using maximum likelihood techniques. Table 2 reports estimates of the beta coefficients and of σ, S. The values for f(Z) and F(Z) can be obtained directly from standard statistical tables. The values for sections 5 and 6, Table 3, can be obtained from previously calculated values.

As an example, the entries in Table 3 were calculated at the overall sample means using Model 1 coefficients:

Variable	Mean	Coefficient
DBH	10.83	1.18
HIVAL	2.60	1.16
HAUL	44.67	−0.18
VALUE	19.28	1.22
Constant	1.00	−17.80
S	——	6.75
ADV	10.30	——

Calculating $XB=13.48$, $XB-ADV=3.18$, and $(XB-ADV)/S=0.47$. Statistical tables for the normal distribution give $F(0.47)=0.68$ and $f(0.47)=0.36$. Substituting these values in the equations listed above yields the values in Table 3.

Sendak, Paul E. 1991. **Timber sale value as a function of sale characteristics and number of bidders.** Res. Pap. NE-657. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 7 p.

Examines the effect of sale characteristics and number of bidders on sale value for timber sold by sealed-bid auction on the Green Mountain National Forest in Vermont. As anticipated from theory and previous empirical studies, increasing the number of bidders tended to increase the winning-bid value for the timber auctions studied. Efforts made to ensure that a timber sale offering received at least one qualified bid had a greater impact on sales revenue than efforts made to increase high-bid value. In designing sales, managers should avoid setting appraisal value too high in relation to timber quality.

Keywords: Appraisal, auctions, national forest, Tobit

☆ U.S. GOVERNMENT PRINTING OFFICE: 1991—548-088/40,005

Headquarters of the Northeastern Forest Experiment Station is in Radnor, Pennsylvania. Field laboratories are maintained at:

Amherst, Massachusetts, in cooperation with the University of Massachusetts

Burlington, Vermont, in cooperation with the University of Vermont

Delaware, Ohio

Durham, New Hampshire, in cooperation with the University of New Hampshire

Hamden, Connecticut, in cooperation with Yale University

Morgantown, West Virginia, in cooperation with West Virginia University

Orono, Maine, in cooperation with the University of Maine

Parsons, West Virginia

Princeton, West Virginia

Syracuse, New York, in cooperation with the State University of New York, College of Environmental Sciences and Forestry at Syracuse University

University Park, Pennsylvania, in cooperation with The Pennsylvania State University

Warren, Pennsylvania

"*Caring for the Land and Serving People Through Research*"