Forest Science, Vol 40, No 3, pp 474–496

The Value of Information Services in a Market for Factors of Production with Multiple Attributes: The Role of Consultants in Private Timber Sales

IAN A. MUNN
RANDAL R. RUCKER

ABSTRACT. The value of information services is incorporated into a hedonic pricing model in the context of private timber sales, where forestry consultants are often hired by landowners selling their timber. A data set containing detailed information on a sample of private sales is used to estimate the effects on bid prices of hiring a consultant. The estimated effects, using an estimation procedure that corrects for the statistical shortcomings of a simple OLS model, indicate that on average the increased price on consultant sales is approximately equal to the prices consultants charge for their services. FOR. SCI. 40(3):474–496.

THE DETERMINATION OF MARKET PRICES for goods and resources with multiple attributes is often modeled in a hedonic pricing framework (Rosen 1974). Empirical applications of this framework have been used to obtain estimates of market-clearing prices of individual attributes of a variety of goods and resources [Bartik and Smith (1987), Brorsen, Grant, and Rister (1984), Follain and Jimenez (1985), Palmquist (1984), Palmquist (1989), Veeman (1987), and Wilson (1984)].

Acquiring information on the market values and attributes of complex goods and resources is costly.[1] Individuals with a comparative advantage in providing such information play an important role in many competitive market settings. Although this point is universally accepted among economists, existing hedonic pricing models, which assume perfect information, fail to acknowledge information-provision explicitly as a valued attribute.

In this paper, we incorporate the value of information services into a hedonic pricing model in the context of private timber sales. Information services on these sales are provided by forestry consultants who are sometimes hired by landowners to assist in the sale of privately owned timber. These consultants provide information on tract attributes, market conditions, and the identities of potential buyers who are likely to place high values on the tract. Although consultants claim to generate higher prices for their clients, after accounting for differences in

[1] See Stigler (1961) for the seminal discussion of this point.

timber volumes and quality, this claim has been difficult to demonstrate empirically.[2]

Timber tracts can be viewed as differentiated factors of production used in the manufacture of lumber, pulp and paper, and other forest products. The timber varies in quantity, quality, species mix, and product class. Tracts also vary by size, location, accessibility, and logging conditions. Because the selling price of a timber tract can reasonably be assumed to be a function of these characteristics, the hedonic model is an appropriate framework for analyzing timber prices. A number of previous studies have used hedonic regressions to estimate the determinants of timber (or stumpage) prices. A few of these studies, including Puttock et al. (1990), Johnson (1979), and Rucker (1984), specifically recognize the hedonic model as the theoretical basis of their analyses. Others have not specifically recognized the hedonic model [Anderson (1969a), Anderson (1969b), Holley (1970), Hubbard and Abt (1989), Jackson (1987), and Jackson and McQuillan (1979)].

This paper examines the effects of consultants within the context of the hedonic model. Section I presents a hedonic model of timber sales. Section II modifies this hedonic model to allow for the role of consultants. Section III describes data from a sample of private North Carolina timber sales and then presents regression results using both simple OLS and more sophisticated estimation procedures that correct for sample selection bias and that model the individual buyers in our data set as separate sources of random variation. The estimated effects of consultants on bid prices are shown to vary substantially between the different estimation procedures. Section IV concludes.

I. A HEDONIC MODEL OF TIMBER SALES

The hedonic model, first developed by Griliches (1971), Rosen (1974), and Freeman (1971) in the context of consumer choice, provides the theoretical basis for the relationship between the price of a good and the quantities of various characteristics embodied in that good. A hedonic model of derived demand for differentiated factors of production, which was developed by Palmquist (1989), is applied to tracts of standing timber in the following discussion.

The selling price of a tract depends on its characteristics (both physical and contractual) and can be represented by a hedonic price equation,

$$P = P(z_1, \ldots z_n), \tag{1}$$

where P is the selling price and the z_i's are the levels of the n characteristics of the tract. This hedonic price equation, which represents the equilibrium price schedule determined by the interactions of demanders (timber buyers) and suppliers (landowners), is assumed to be exogenous to any individual.

[2] Hubbard and Abt (1989), for example, using a small sample of private timber sales in Florida find that consultant sales have higher bid prices, but only on tracts with certain characteristics. Hardie and Wieland (1987), using data on Maryland timber sales, find that the mean price on consultant sales is significantly higher than on nonconsultant sales, but then indicate that this difference is not significant when differences in tract characteristics are taken into account. Larson and Hardie (1989), who model landowner acquisition of information in an expected utility maximization framework, find that acquisition of information (either by obtaining a stumpage inventory or by hiring a consultant) significantly affects sales values.

In the following discussion, the demand side of the stumpage market is modeled as the conversion of standing timber into products delivered to the mill gate. Buyers use standing timber as an input in the production of delivered products. The logging production function can be written in implicit form as,

$$\mathrm{l}(x,z,w) = 0, \tag{2}$$

where x is a vector of netputs that excludes the timber tract (x's > 0 are outputs and x's < 0 are inputs), z is a vector of timber tract characteristics, and w is a vector of buyer characteristics that affect productive ability. The w vector manifests itself in differences among buyers in size of operation, degree of mechanization, area of specialization and efficiency.

The maximum amount a buyer will be willing to pay for a given tract of timber depends on the gross profit,[3] defined here as the difference between the buyer's total revenues and nontimber input costs such as harvesting and delivery costs and the opportunity costs of the buyer's time and capital. A buyer's objective is to maximize gross profits subject to the production function. This maximization problem can be written as

$$\max_{x} G\pi_B = \sum_{i=1}^{n} p_i x_i, \quad \text{s.t.} \quad \mathrm{l}(x,z,w) = 0, \tag{3}$$

where $G\pi_B$ is the buyer's gross profit and p_i is the price for the ith netput—delivered prices for various products (outputs) to various mills and prices for nontimber inputs. Solving this maximization problem results in supply and factor demand equations which can, in turn, be used to derive a gross profit function, $G\pi_B^*(z,p,w)$. Actual profit is the gross profit minus the amount paid for the tract. The maximum amount a buyer would be willing to pay for a tract of timber is the gross profit function evaluated at the relevant z, p, and w values minus the desired level of actual profit.[4] The buyer's bid function is therefore

$$\mathrm{Bid}(z,\ p,\ w,\ \pi_B^d) = G\pi_B^* - \pi_B^d \tag{4}$$

where π_B^d is the buyer's desired profit and z, p, and w are vectors as previously described.

On the supply side, the landowner seeks to maximize profits from the sale of his or her tract of timber. The characteristics of the tract can be divided into two groups: controllable and uncontrollable. A landowner will attempt to maximize profits by altering those characteristics under his or her control. The landowner's problem is to

$$\max_{z_c} \pi_{LO} = P(z_c,z_u) - C^*(z_c,z_u,r,v), \tag{5}$$

[3] Palmquist uses the term variable profits for the same concept.

[4] The term "desired level of profit" is used elsewhere in the hedonic literature [see, for example, Palmquist (1989)]. If all relevant economic costs are included in the expression for gross profits, and if there is competition among timber buyers, then the maximum expected attainable level of actual profits is zero. In this case, the equilibrium bid price will be a point on the zero-profit contour of the buyer's bid function.

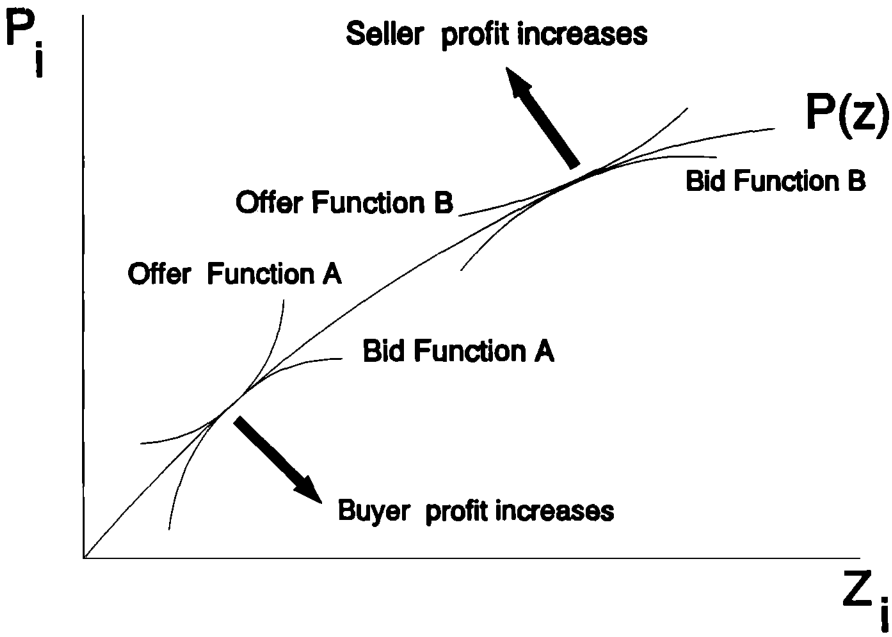

FIGURE 1

where π_{LO} is the landowner's profits, P is the equilibrium hedonic price schedule, C^* is the landowner's cost function for selling the tract, z_c is a vector of tract characteristics controlled by the landowner, z_u is a vector of tract characteristics not under the control of the landowner, r is a vector of input prices, and v is a vector of landowner characteristics that influence productive capabilities. Solving this maximization problem leads to the landowner's offer function in a similar progression of steps as for the buyer's bid function. This offer function, which shows the minimum price at which a landowner would agree to sell his timber, is

$$\text{Offer}(z_c, z_u, \pi_L^d, r, v) = \pi_L^d + C^*, \tag{6}$$

where π_L^d is the landowner's desired profits.[5] The equilibrium price schedule is traced out by the points of tangency between the bid and offer functions as shown for a particular characteristic (z_i) in Figure 1, where Offer Functions A and B represent the isoprofit curves from the offer functions of two different sellers and Bid Functions A and B represent the isoprofit curves from the bid functions of two different buyers.

II. THE ROLE OF CONSULTANTS IN THE HEDONIC MODEL

The element of the z_c vector discussed above that is the primary focus here is the information services provided by a consultant. Of particular interest is the in-

[5] As with the buyer's "desired profits," if all the relevant economic costs are included in the landowner's cost function and if there is competition among landowners, then the maximum expected attainable level of landowner profit is zero. In this case, the equilibrium offer price will be a point on the zero-profit contour of the landowner's offer function.

crease in price that results when a landowner hires a consultant. Under the assumptions of the standard hedonic pricing model, however, consultants are unable to increase the prices that landowners receive for their timber. In the standard model, perfect information on all relevant attributes of each tract is obtained at no cost and attribute prices are at competitive equilibrium levels. Any attempt by a consultant to generate higher prices fails because buyers substitute other tracts at the market price, leaving the consultant's tract unsold.

If the assumption of costless information is relaxed, however, consultants' services can result in increased prices. Many private landowners rarely sell timber, are unfamiliar with current market prices when they do sell, and lack the necessary forestry expertise to determine the levels of the various attributes of their tract. In contrast, buyers have experience at determining timber volumes and other tract attributes and are cognizant of current market prices. Therefore, for any given amount of time spent measuring tract attributes, there is less uncertainty concerning a buyer's valuation of the tract than there is concerning the seller's valuation—a buyer is likely to have a relatively accurate estimate of the maximum amount he or she can pay for the tract, while a landowner will have less accurate estimates of both the true characteristics of the tract and the market value of those characteristics. As a consequence of this informational disparity, a landowner is likely to be at a disadvantage when negotiating with one or two buyers.[6]

The net result of this informational disparity is that the observed hedonic price schedule will differ from the $P(z)$ function in Figure 1. If a landowner's offer price is too high, no buyer will purchase the tract. If the landowner's offer price is too low, buyers will readily purchase the tract. This feature of the market thus implies that the market price schedule estimated on the basis of actual transactions will lie below the costless-information-competitive-equilibrium hedonic price schedule. This result is shown graphically in Figure 2.

Another reason for a lower observed market price schedule with costly information is that individual buyers will not know of every timber tract for sale. Therefore, the buyer with the highest valuation may not bid on a given tract. The seller, who is relatively uncertain of the true value of his tract, accepts the highest bid among those offered. Again, the estimated price schedule will be lower than the costless-information-competitive-equilibrium price schedule. This effect is shown in Figure 3.

Clearly, an avenue now exists for consultants to increase the price received by their clients. Using their expertise, consultants can help landowners formulate more accurate tract valuations and notify high-value prospective buyers that a tract is for sale.[7] If, on average, consultants are able to help sellers overcome

[6] Because one type of costly information is the identities of the highest valued buyers of different attributes, negotiating with only one or two buyers may be optimal for sellers who enter the market infrequently.

[7] The more accurate tract valuation associated with a sale involving a consultant increases bid prices in a manner other than that shown in Figures 2 and 3. Buyers' incentives to expend resources on presale measurement (cruising) will be reduced as a result of the better information contained in consultant-provided cruises. In a competitive setting, such a reduction in cruising expenses will increase the winning bid price. See Leffler and Rucker (1991) for a detailed discussion of this issue in the context of timber sales, and Barzel (1982) and French and McCormick (1984) in a more general context.

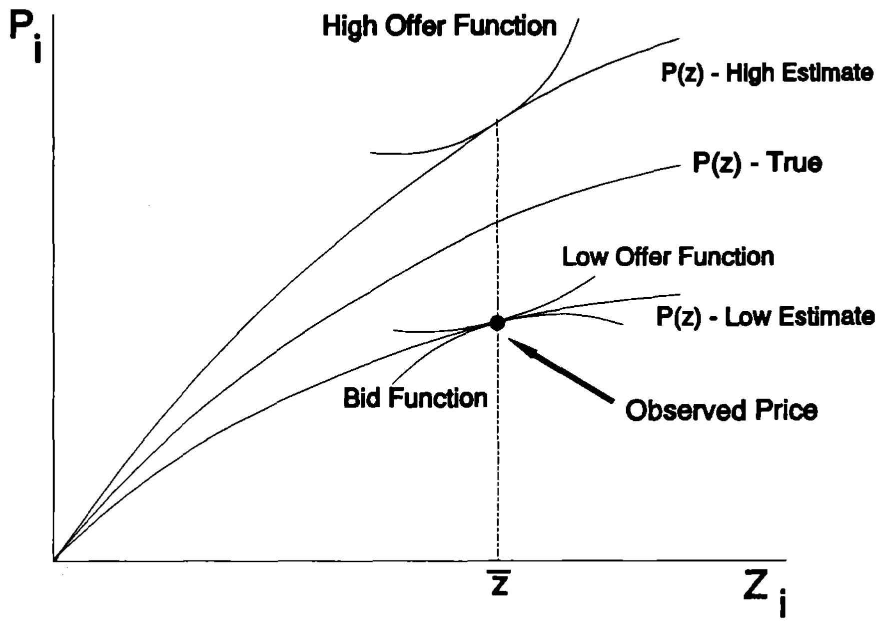

FIGURE 2

their informational disadvantages *vis a vis* buyers, the estimated price schedules for consultant sales will be higher than for nonconsultant sales.

This discussion of the effects of consultants on timber sale prices, which can be modified in a straightforward manner to nontimber contexts in which the provision of information services is of value, suggests that the hedonic price function given by Equation (1) above can be rewritten as

$$P = P(z_1, \ldots z_n, I), \tag{7}$$

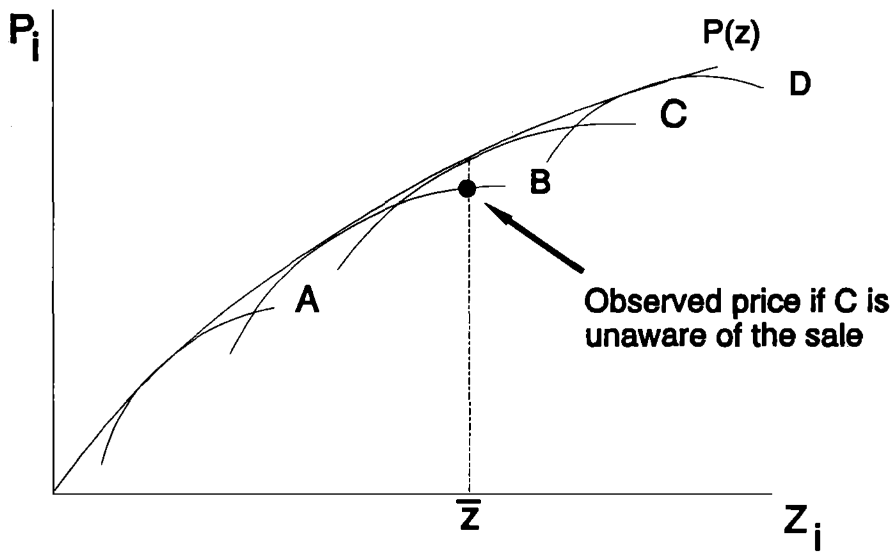

FIGURE 3

where I represents an additional characteristic of the sale—the level of information available on the other attributes of the sale. Empirical estimates of the value of this information are presented below.

III. DATA, EMPIRICAL SPECIFICATION, AND ESTIMATION RESULTS

The data for this study consist of information on a sample of 298 timber sales from the mountain, piedmont, and coastal regions of North Carolina during the period 1986–1991. Data collection was initiated by mailing to all timber buyers listed in *1989 Buyers of Forest Products in North Carolina* a brief description of the study and a request to indicate whether they would be willing to participate. Those who agreed to participate were mailed sale questionnaires that asked detailed questions about individual sales. Among the tract characteristics collected for each sale are timber volumes (reported by species and product class); timber quality (rated by buyers as poor, below average, average, good, or excellent); logging and access conditions (rated in the same way as quality); acres in the tract; and county location (which was used to identify the geographic region of the sale). In addition, the timber sale was classified as "clearcut" if all merchantable timber was designated to be cut, as "partial cut" if only a portion of the trees were to be cut, or as "salvage cut" if the trees had to be harvested quickly due to some unexpected event (usually a natural calamity). The contract length was recorded either in months or as "open" if the contract did not specify a termination date.

For lump-sum sales, the purchase price for the tract was either the winning bid for sealed-bid auction sales or the agreed upon price for negotiated sales. For per unit sales, respondents usually reported the total amount paid over the life of the contract. In those cases where respondents reported only the listed per unit prices, the purchase price is calculated by multiplying the per unit price for each species by the corresponding volumes and then summing over species. Because the data include sales from several years, actual prices were deflated by the Producer Price Index for intermediate goods.

EMPIRICAL SPECIFICATION

The price paid for a tract of timber is determined by its hedonic characteristics, implying an empirical specification of the form:

$$\begin{aligned} PRICE_i = f(&VOLPSAW_i, VOLHWSAW_i, VOLPPULP_i, VOLHWPULP_i, \\ &VOLC\&SAW_i, VOLOTH_i, QUALDUM_i, ACRES_i, DISTANCE_i, \\ &ACCESSDUM_i, CCUTDUM_i, PCUTDUM_i, SALVDUM_i, \\ &CLENGTH_i, OPEN_i, COASTDUM_i, MTDUM_i, PIEDDUM_i, \\ &CONSULT_i) \end{aligned} \tag{8}$$

where, for the ith sale,

$PRICE_i$ = price paid for the tract (per ac),

$VOLPSAW_i$ = volume of pine sawtimber per ac (mbf-Scribner),

$VOLHWSAW_i$ = volume of hardwood sawtimber per ac (mbf-Doyle),

$VOLPPULP_i$ = volume of pine pulpwood per ac (cords),

$VOLHWPULP_i$ = volume of hardwood pulpwood per ac (cords),

$VOLPC\&SAW_i$ = volume of pine chip-n-saw per ac (cords),

$VOLOTH_i$ = volume of miscellaneous other species per ac (mbf-Doyle),

$QUALDUM_i$ = quality dummy variable (1 if excellent, 0 otherwise),

$ACRES_i$ = acres in the tract,

$DISTANCE_i$ = distance from tract to buyer's mill,

$ACCESSDUM_i$ = access dummy variable (1 if both access and logging conditions were rated as good or better, 0 otherwise),

$CCUTDUM_i$ = clearcut dummy (1 for clearcut sales, 0 otherwise),

$PCUTDUM_i$ = partial cut dummy (1 for partial cut sales, 0 otherwise),

$SALVDUM_i$ = salvage dummy (1 for salvage sales, 0 otherwise),

$CLENGTH_i$ = contract length in months,

$OPEN_i$ = dummy for sales with open lengths (1 if open, 0 otherwise),

$COASTDUM_i$ = dummy for coastal plain region sales (1 if coastal plain, 0 otherwise),

$MTDUM_i$ = dummy for mountain region sales (1 if mountain, 0 otherwise),

$PIEDDUM_i$ = dummy for piedmont region sales (1 if piedmont, 0 otherwise),

$CONSULT_i$ = dummy for consultant sales (1 if consultant, 0 otherwise).

Summary statistics for these variables are presented in Table 1. Because the estimated regression model includes a constant term, the dummy variables for clearcut sales (*CCUTDUM*) and coastal region sales (*COASTDUM*) are omitted to allow inversion of the $X'X$ matrix. The coefficients on *PCUTDUM* and *SALVDUM* therefore are interpreted as differences from the price of clearcut sales and the coefficients on *PIEDDUM* and *MTDUM* are interpreted as differences from the price of coastal plain sales.

The estimated coefficients on the volume variables, *VOLPSAW, VOLHWSAW, VOLPPULP, VOLHWPULP, VOLPC&SAW,* and *VOLOTH,* represent the additional values of a unit of each type of timber. Insofar as stumpage values are positive, the predicted signs of these coefficients are all positive. The estimated coefficient on *QUALDUM* is expected to be positive because an increase in quality should increase the price of the tract. For *ACRES,* the estimated coefficient is expected to be positive. An increase in acreage, holding the volumes per acre constant, increases the total volume on the tract. As the volume on tracts

TABLE 1.

Summary statistics for key variables from a sample of timber sales in North Carolina from 1986 through 1991.

Variable	Full Mean	Full Std dev	Consultant Mean	Consultant Std dev	Nonconsultant Mean	Nonconsultant Std dev
PRICE	669.86	629.24	934.46	747.87	525.90	500.39
VOLPSAW	2.95	3.65	3.85	4.05	2.45	3.32
VOLHWSAW	1.46	2.45	2.00	3.20	1.16	1.87
VOLPPULP	3.86	5.22	3.28	3.70	4.18	5.86
VOLHWPULP	3.93	6.64	4.30	5.48	3.73	7.20
VOLPC&SAW	0.87	1.94	0.59	1.41	1.02	2.16
VOLOTH	0.10	0.44	0.05	0.33	0.12	0.49
QUALDUM	0.15	0.36	0.21	0.41	0.12	0.32
ACRES	62.12	85.62	73.07	80.43	56.15	87.95
DISTANCE	36.59	24.82	42.13	28.17	33.57	22.29
ACCESSDUM	0.39	0.49	0.42	0.50	0.37	0.48
CCUTDUM	0.74	0.44	0.75	0.43	0.74	0.44
PCUTDUM	0.21	0.41	0.24	0.43	0.20	0.40
SALVDUM	0.04	0.20	0.01	0.10	0.06	0.24
CLENGTH	18.53	10.52	22.28	9.08	16.49	10.70
OPEN	0.08	0.27	0.02	0.14	0.11	0.32
COASTDUM	0.50	0.50	0.50	0.50	0.50	0.50
PIEDDUM	0.36	0.48	0.39	0.49	0.34	0.48
MTDUM	0.14	0.35	0.10	0.31	0.16	0.37
CONSULT	0.35	0.48	—	—	—	—
No. of observations	298		105		193	

increases, the number of moves between tracts is reduced with an associated reduction in moving costs and increase in per acre bid price. The expected sign on *DISTANCE* is negative—the farther the tract is from the mill, the higher the hauling costs and the lower the value of the timber. The coefficient on *ACCESSDUM* is expected to be positive because a tract with good access and logging conditions will have low logging and transportation costs and can be logged in all weather thereby helping to offset wet weather shortages. The expected sign on *PCUTDUM* is negative because more care must be exercised to protect the remaining trees. The expected sign on *SALVDUM* is negative because the sale occurs under duress as in the case of Hurricane Hugo. The signs on the regional dummies, *PIEDDUM* and *MTDUM* are ambiguous because there is no *a priori* reason to expect prices to be higher or lower for any of the regions. *CLENGTH* should have a positive coefficient because increasing the contract length gives the logger greater flexibility. By the same logic, the predicted sign of the coefficient on *OPEN* also is positive.

In the specification of Equation (8), the effect on bid prices of consultant-provided information and services is measured by the coefficient on the variable *CONSULT*, which is predicted to be positive. This specification, however, allows consultants to affect bid prices only through changes in the intercept of the regression and constrains the coefficients on all the explanatory variables to be equal for consultant and non-consultant sales. We relax this constraint by estimating an alternative empirical specification that includes multiplicative interaction variables between the *CONSULT* dummy and the other explanatory variables. This allows for the possibility that the changes in bid prices that result from hiring consultants may depend on the physical and contractual characteristics of the sale. We hypothesize that the value of a consultant will be greatest on tracts whose values are most uncertain and difficult to estimate.[8] An important determinant of the level of uncertainty concerning the value of a tract is the composition of the timber on the tract. North Carolina forests contain pine and hardwood sawtimber, which can be quite variable in value, and pine chip-n-saw and pulpwood timber, which are relatively homogeneous in value. We therefore predict that the greater the volume of pine and hardwood sawtimber on a tract (holding constant the volumes of other types of timber on the tract), the greater the value of a consultant.

Both the specification with the *CONSULT* dummy alone and the specification with the interactive variables are discussed below.[9]

RESULTS: SIMPLE OLS

Table 2 displays the OLS estimation results for the two specifications of the model, where Version 1 contains the *CONSULT* dummy only and Version 2 includes the interactive variables in addition to the *CONSULT* dummy.[10] The reported F-values indicate that the nonintercept variables are jointly significant at the 0.01 level for both models. The estimated coefficients on the explanatory variables are generally significantly different from zero, have the predicted signs, and are robust with respect to the specification of the model.[11] All of the estimated coefficients on the volume variables are highly significant and have magnitudes close to the market prices for stumpage reported by Timber Mart-South. For 1990, Timber Mart-South prices (deflated to 1982 = 100 for consistency with the estimated regression coefficients) were: \$124/mbf for pine sawtimber, \$72/mbf for miscellaneous hardwood sawtimber, \$29/cord for pine chip-n-saw, \$11/cord for pine pulpwood, and \$6/cord for hardwood pulpwood. The corresponding estimated coefficients for Version 1 are \$139.09 for pine sawtimber, \$80.79 for hardwood sawtimber, \$28.33 for pine chip-n-saw, \$15.75 for pine pulpwood, and \$5.43 for hardwood pulpwood.

[8] See Munn (1993) for further discussion of this issue.

[9] An issue of potential interest concerns the relationship between the effects on bid prices of hiring a consultant and using a sealed bid auction (rather than negotiating) to sell a timber tract. A number of the buyers surveyed suggested that any increase in bid prices on consultant sales likely was due in part to the fact that consultants typically sell tracts using sealed bid auctions, which (the buyers felt) bring higher prices than negotiated sales. Indeed, in our sample most of the consultant sales (83%) are sealed bid auction sales. To separate the effects on bids of consultants due to the information they provide from their effects due to choice of sale methods, we ran regressions analogous to those reported in the text that included a zero-one dummy variable to identify sealed-bid auction sales. The conclusions drawn from these regressions concerning the effects of consultants on bid prices are substantively the same as those reported in the text. An appendix discussing the details of this investigation is available on request from the authors.

[10] The results reported below are for linear specifications of the bid price equation. Other specifications estimated included log-log, semi-log, and inverse semi-log. The linear specification was chosen based on the criterion of minimum residual sum of squares. See Rao and Miller (1971, p. 107–111) or Box and Cox (1964) for a discussion of the transformation required for direct comparison of the residual sums of squares from the linear and log specifications.

[11] A one-tailed test is employed when the sign of the coefficient is predicted by the model. A two-tailed test is used when there is no sign prediction.

TABLE 2.

Hedonic price equations for timber sales in North Carolina: Simple OLS.[a]

	Version 1		Version 2	
Variable	Coef. est	t-value	Coef. est	t-value
INTERCEPT	−64.90	−1.30	−25.84	−0.50
VOLPSAW	139.09	31.96***	126.10	23.81***
VOLHWSAW	80.79	12.54***	78.22	7.02***
VOLPPULP	15.75	5.32***	15.35	4.68***
VOLHWPULP	5.43	2.39***	4.57	1.69*
VOLPC&SAW	28.33	3.69***	32.30	3.99***
VOLOTH	94.60	2.92***	100.52	2.88***
QUALDUM	246.56	5.99***	238.48	5.87***
ACRES	0.08	0.45	0.10	0.59
DISTANCE	−0.70	−1.18	−0.70	−1.21
ACCESSDUM	10.06	0.36	8.06	0.30
PCUTDUM	−3.71	−0.95	−5.22	−0.14
SALVDUM	−249.96	−3.56***	−226.87	−3.29***
MTDUM	−111.74	−2.24##	−97.92	−1.93##
PIEDDUM	−72.98	−2.30##	−67.05	−2.16##
CLENGTH	3.84	2.21**	3.28	1.93**
OPEN	97.25	1.58*	98.90	1.64*
CONSULT	128.59	4.21***	24.22	0.44
*CON*VOLPSAW*	—	—	32.96	4.32***
*CON*VOLHWSAW*	—	—	6.68	0.51
*CON*VOLPPULP*	—	—	−6.00	−0.79
*CON*VOLHWPULP*	—	—	5.44	1.11
*CON*VOLPCSAW*	—	—	−14.65	−0.78
*CON*VOLOTH*	—	—	−52.49	−0.67
F VALUE	118.09		93.02	
ADJ. R^2	0.8701		0.8769	
No. of observations = 298				

[a] Significance levels for t-values in Tables 2, 3, and 4 are as follows. Two tailed significances: # = significant at 0.10 level; ## = significant at 0.05 level; and ### = significant at 0.01 level. One tailed significances: * = significant at 0.10 level; ** = significant at 0.05 level; and *** = significant at 0.01 level.

The estimated coefficients on *QUALDUM* and *SALVDUM* are significant at the 0.01 level, while the coefficients on *CLENGTH* and *OPEN* are significant at the 0.05 or 0.10 level, respectively. All of these coefficients have the predicted signs. The coefficients for *MTDUM* and *PIEDDUM* are negative and significant at the 0.05 level, indicating that, *ceteris paribus*, timber tract prices are lower in the mountains and piedmont than in the coastal plain.

In Version 1, the coefficient on *CONSULT* is of primary interest for the purposes of this article. The estimated value of this coefficient is 128.59 and is significant at the 0.01 level. Based on this estimate, the null hypothesis that the effect of a consultant on sale price is zero can be rejected. This estimate also suggests that, on average, the consultant-induced increase in prices exceeds the consultant's fees as is seen by the following calculations. The 90% confidence interval on the estimated coefficient on *CONSULT* in Version 1 is from $78 to $179. The predicted bid for Version 1, evaluated at the means of the explanatory variables and assuming a consultant increases bids by $128.59, is $753.44/ac. On average, consultants in North Carolina charge 8.3% of the sale price of the tract for their services (Kronrad and Albers 1983). Thus for our sample, the average consultant's fee is \$62.54/ac, which is less than the lower bound on the above confidence interval.

An important issue concerns the possibility that *CONSULT* is endogenous. Using the Wu-Hausman specification test, we could not reject the null hypothesis that *CONSULT* is exogenous.[12] This result makes intuitive sense. The seller of a tract of timber must make a number of simultaneous decisions concerning the sales provisions for the timber. At the time of the sale, however, when the bid price is determined, whether or not a consultant was hired is predetermined (or exogenous) from the perspective of the buyers bidding on the tract.

Results: OLS with Consultant Interactive Variables

The specification displayed for Version 2 was chosen as follows. An F-test rejected (at the 0.05 level) the null hypothesis that the coefficients on the interactive variables are jointly equal to zero. We then separated the explanatory variables into "timber volume" and "other" variables. Additional F-tests (1) failed to reject the null that the "other" variables are jointly equal to zero, and (2) rejected the null that the "timber volume" variables are jointly equal to zero. Accordingly, the results for Version 2 reported below are for a specification that includes only the *CONSULT* dummy variable and the timber volume interactive variables.

The effect on bid prices of hiring a consultant implied by this model is

$$\begin{aligned} \partial PRICE/\partial CONSULT = {} & 24.22 + 32.96 \cdot VOLPSAW + 6.68 \cdot VOLHWSAW \\ & - 6.00 \cdot VOLPPULP + 5.44 \cdot VOLHWPULP \\ & - 14.65 \cdot VOLCPC\&SAW - 52.49 \cdot VOLOTH \end{aligned} \tag{9}$$

Only the interactive variable with *VOLPSAW* is significantly different from zero in this specification. This implies that, for our data sample using simple OLS estimators, the value of a consultant increases only as the volume of pine sawtimber per acre on a tract increases.[13] Setting the values of the statistically insignificant coefficients in (9) to zero, the value of a consultant at the sample mean for *VOLPSAW* is

$$\partial PRICE/\partial CONSULT = 32.96 \cdot 2.95 = \$97.23 \tag{10}$$

This estimated value is not significantly different from the estimated effects of a consultant in Version 1.[14] The predicted bid for Version 2, evaluated at the means

[12] Details of the endogeneity test are available from the authors upon request. See Wu (1973), Hausman (1978), or Thurman (1986) for a description of this test.

[13] The lack of significance on the interactive term between *CONSULT* and *VOLHWSAW* is contrary to our expectations. The "mixed model" estimator discussed below, however, yields a marginally significant positive coefficient on this variable.

[14] With respect to the insignificant parameter estimates in Table 2 and Equation (9), it could be argued that because there are numerous nonzero values of these estimates that also could not be rejected, it is not appropriate to set them equal to zero. If instead, we set them equal to their estimated values, the implied value of a consultant is \$111, which again is not significantly different from the version 1 estimate. Alternatively, it might be argued that the *CONSULT* dummy and all of the interactive coefficients other than *CON*VOLPSAW* could be dropped from Version 2. Doing this has no substantive effect on the results—the estimated coefficient on *CON*VOLPSAW* in such a

of the explanatory variables and assuming a consultant is involved is $715.47.[15] Assuming again a commission charge by consultants of 8.3%, the average consultant's fee is $59. The standard error of the estimated value in (10) is $22.51, implying that the lower bound on the 90% confidence interval for this estimate is $60. As with Version 1, therefore, the Version 2 estimates suggest that the consultant-induced increase in price exceeds the consultant's fees.

Results: Correcting for Sample Selection Bias

To further investigate the determinants of bid prices and in particular the effects of consultants on timber prices, we re-estimate our model using econometric methods designed to deal with two potential sources of bias and inconsistencies in our OLS results. First, we use the approach developed by Heckman (1979) to correct for sample selection bias. In the current context, where surveys were used to obtain data on timber sales, the concern is that if certain groups of buyers (for example, loggers as compared to dealers) are more likely to participate in our survey than other groups, and if those groups paid systematically different prices for timber than other groups, then the estimated OLS coefficients will be biased. Second, we decompose the error term in our model into two sources of random variation—between buyers and within buyers to investigate the possibility that different buyers may behave differently when bidding for timber and that this may affect our estimates of the importance of different factors in determining bid prices.

To implement Heckman's approach for correcting for sample selection bias, we estimate an inverse Mills ratio for our data sample and then re-estimate the OLS model with this ratio included as a right hand side variable.[16] The estimation results, which are shown in Table 3, indicate that the estimated coefficient on the inverse Mills ratio (*MILLS*) is negative and significantly different from zero in both versions of the model. These results suggest that sample bias does exist and that this bias is correlated with differences in timber bid prices. More importantly for our purposes, however, even though the *MILLS* coefficient is significant, this modification of the estimation procedure has little effect on the estimated coefficients on the other variables and no effect on the conclusions concerning their statistical significance. In particular, the earlier conclusions with respect to the significance and magnitude of the effects of consultants on bid prices are unaffected.

Results: Buyers as Random Effects

In the previous discussion, an implicit assumption was that the bid price per acre was independent of the buyer supplying the information. If buyer bidding behavior differs sytematically, then this assumption is not appropriate. To examine the effects on our estimation results of allowing buyer-specific effects, we treat each

specification is 34.49, implying a consultant effect of $101.75 at the sample mean for *VOLPSAW*. Additional results reported below are also robust to such a change (as well as a variety of other changes) in specification.

[15] This estimate, like the estimate of the value of a consultant in Equation (10), is calculated by setting the values of the statistically insignificant coefficients in (9) to zero.

[16] The details of this procedure are discussed in the appendix.

TABLE 3.

Hedonic price equations for timber sales in North Carolina: Corrected for sample selection bias.

	Version 1		Version 2	
Variable	Coef est	t-value	Coef est	t-value
INTERCEPT	62.13	0.82	116.72	1.56
VOLPSAW	139.40	16.86***	125.89	10.37***
VOLHWSAW	82.19	8.36***	81.30	4.73***
VOLPPULP	14.74	4.33***	14.15	3.68***
VOLHWPULP	4.35	2.24**	3.23	1.35*
VOLPC&SAW	32.18	4.21***	37.30	5.27***
VOLOTH	89.75	3.52***	95.99	4.13***
QUALDUM	248.48	4.39***	240.37	4.32***
ACRES	0.10	0.95	0.12	1.22
DISTANCE	−0.54	−0.95	−0.54	−1.00
ACCESSDUM	4.80	0.16	1.57	0.06
PCUTDUM	5.24	−0.15	4.05	0.11
SALVDUM	−213.86	−1.85**	−185.09	−1.88**
MTDUM	−133.97	−2.16##	−123.44	−2.05##
PIEDDUM	−88.57	−2.73###	−84.81	−2.74###
CLENGTH	3.69	2.66***	3.07	2.40***
OPEN	64.55	1.41*	61.43	1.43*
CONSULT	121.88	4.16***	16.89	0.30
CON*VOLPSAW	—	—	34.08	2.48***
CON*VOLHWSAW	—	—	4.60	0.22
CON*VOLPPULP	—	—	−5.00	−0.60
CON*VOLHWPULP	—	—	5.27	0.93
CON*VOLPC&SAW	—	—	−18.64	−0.98
CON*VOLOTH	—	—	−56.45	−1.00
MILLS	−78.86	−2.53##	−87.47	−3.01###
F VALUE	113.79		91.6	
ADJ. R^2	0.8724		0.8798	
No. of observations = 298				

Note: The t-values in this table are based on the adjusted standard errors.

buyer as a "random" effect.[17] In this approach, the observations provided by a single buyer are analogous to replications within a block in a controlled experiment. There may be two sources of random variation; between buyers and within buyers. The model specification is now

$$Y_{ij} = X_{ij}\beta + \mu_i + \epsilon_{ij}, \tag{11}$$

where μ is an unknown vector of random effects with i denoting the buyer that supplied the data and j indicating the individual sales reported by buyer i. There is a combination of fixed effects, β, and random effects, μ (with all sales for buyer

[17] These buyer effects also could be estimated using a fixed effects model. Our use of the random effects model is based on the results of a Wu-Hausman specification test for choosing between the random and fixed effects models. See Judge et al. (1985) for a discussion of this test. Also, see Munn (1993) for a theoretical justification for using a random effects model in the present context.

i having a common value for μ). In this "mixed" model, statistical inference with respect to β depends on both ϵ and μ.[18]

Values of ϵ are assumed to be uncorrelated, as are values of μ. In addition, ϵ and μ are assumed to be uncorrelated with each other and the expected value of each is zero. The variance of the two error terms can be modeled in a variety of ways. A standard assumption is:

$$E[\epsilon_{ij}^2] = \sigma_\epsilon^2$$

$$E[\mu_i^2] = \sigma_\mu^2 \tag{12}$$

Under this assumption, the within buyer error terms, ϵ_{ij}, are all drawn from the same population with variance, σ_ϵ^2. The alternative assumption used for the estimation results reported below is:

$$E[\epsilon_{ij}^2] = \sigma_{\epsilon_i}^2$$

$$E[\mu_i^2] = \sigma_\mu^2 \tag{13}$$

Here, for each of the i buyers, the within buyer error terms are assumed to be drawn from different populations, each having a buyer-specific variance. This specification of the model is general enough to allow for systematic differences in buyer bidding behavior, both in terms of average bids and in the variation in bids of different buyers.

This mixed model is estimated using the *PROC MIXED* procedure in SAS.[19] The least restrictive version of this model, with different error structures for each buyer, would not converge. This appears to be due to the fact that some buyers provided information on three or fewer sales. To circumvent this problem, we divide buyers into four groups based on the size of operation in which they are involved and estimate a different error structure for each size group.[20] The results of this estimation procedure are reported in Table 4.[21]

Table 4 displays the coefficient estimates of the mixed model for the hedonic price equations. The likelihood ratio test statistics in this table provide a comparison of the mixed models with the linear models of Table 3. These statistics, which are distributed χ^2 with 4 degrees of freedom (the number of *SIZE* groups), strongly reject the null hypothesis that the buyer effects are jointly zero. This

[18] See Steel and Torrie (1980, p. 218–221), Greene (1990, p. 481–486) or SAS Technical Report P-229 (1992, p. 290) for discussions of mixed models.

[19] This procedure allows the estimation of separate variance components for each random effect and for the residual error. It also allows the user to model a variety of covariance structures and automatically incorporates the correct variance terms into test statistics. For a detailed description of *PROC MIXED* see SAS Technical Report P-229 (1992, p. 289–364).

[20] Operation size is measured by daily manufacturing capacity as reported in *1989 Buyers of Forest Products in North Carolina.* We also estimated specifications in which the buyer portion of the error term is assumed to have the same variance for all buyers, and in which buyers are grouped according to the type of their operations. There is no substantive difference between the parameter estimates in these models and the parameter estimates in the model reported in the text. See Munn (1993) for a discussion of these results.

[21] A likelihood ratio test rejects (at the 0.01 level) the null hypothesis of equality of the residual variances for the size groups. A z-test rejects (at the 0.01 level) the null hypothesis that all buyers pay the same prices for timber.

TABLE 4.

Hedonic price equations for timber sales in North Carolina: Mixed model with covariance structure based on SIZE groupings.

Variable	Version 1		Version 2	
	Coef est	t-value	Coef est	t-value
INTERCEPT	187.74	1.68#	217.14	2.04##
VOLPSAW	140.91	35.18***	131.82	27.32***
VOLHWSAW	83.47	13.05***	77.60	9.00***
VOLPPULP	11.66	5.02***	10.71	4.56***
VOLHWPULP	2.29	1.26	2.02	1.01
VOLPC&SAW	37.81	5.59***	39.42	5.87***
VOLOTH	56.03	2.12**	90.31	2.64***
QUALDUM	207.59	6.89***	206.73	6.95***
ACRES	0.15	1.27	0.18	1.48*
DISTANCE	−2.04	−3.60***	−2.10	−3.83***
ACCESSDUM	−2.08	−0.10	3.23	0.15
PCUTDUM	5.19	0.17	8.17	0.27
SALVDUM	−57.05	−0.92	−32.86	−0.55
MTDUM	−134.22	−2.55##	−145.37	−2.82###
PIEDDUM	−89.51	−2.27##	−89.40	−2.34##
CLENGTH	3.59	2.31**	2.80	1.83**
OPEN	61.23	1.02	58.42	0.97
CONSULT	63.32	2.89***	4.09	0.10
*CON*VOLPSAW*	—	—	20.53	3.23***
*CON*VOLHWSAW*	—	—	14.19	1.37*
*CON*VOLPPULP*	—	—	−4.39	−0.92
*CON*VOLHWPULP*	—	—	2.68	0.82
*CON*VOLP&CSAW*	—	—	−2.20	0.17
*CON*VOLOTH*	—	—	−55.75	−1.18
MILLS	−88.67	−1.41	−87.28	−1.48
Null LRT χ^2 (df = 4)	90.91		81.82	
No. of observations = 298				

alternative estimation procedure alters the conclusions to be drawn from the analysis for a few variables—the coefficients on *VOLHWPULP, SALVDUM,* and *OPEN* are no longer significant at standard confidence levels, while the coefficient on *DISTANCE* becomes significant.

The most notable change in the coefficient estimates is in the magnitudes of the estimated coefficients on the variables measuring the effects of consultants on bid prices. In Version 1, the coefficient on *CONSULT* remains significant, but the coefficient is only about half as large as in the earlier models (Tables 2 and 3). Similarly, in Version 2 the coefficient on the interactive term between *CONSULT* and *VOLPSAW* remains significant, but is considerably smaller in magnitude. In addition, the estimated coefficient on *CON*VOLHWSAW* is positive and marginally significant (the one-tailed p-value is 0.086), providing evidence that consultants may also increase the value of tracts with hardwood sawtimber. At the sample means of *VOLPSAW* and *VOLHWSAW,* the estimated effect of a consultant on bid prices is $20.53 \cdot 2.95 + 14.19 \cdot 1.46 = \$81.28$, with a standard error of \$26. This estimate is about 25% smaller than the corresponding value from Table 2.

Comparing these estimates of the effects of consultants with the average fee charged by consultants (between \$50 and \$60 per ac) alters the earlier conclusion that the impact of consultants on bid prices is significantly greater than the price they charge. The conclusion from Table 4, in which corrections are made for the statistical shortcomings of the simple OLS estimation procedure, is that on average the fee charged by consultants is not significantly different from the increase in price resulting from the services they provide. We interpret this result, which is consistent with our prior expectations concerning the effects of competition among consultants in a market setting, as providing a general indication of the validity of our approach to estimating the increase in prices from hiring consultants. We do not claim, of course, that our approach provides precise estimates of all the benefits and costs associated with hiring a consultant. On the benefits side, our analysis measures the value of consultants through the increase in price that results from their involvement. Such estimates of the benefits of consultants underestimate the true value of using a consultant insofar as consultants perform tasks that reduce the costs of selling a tract of timber without affecting the price. As an example, consultants likely can organize and conduct an auction sale at considerably lower cost than a landowner who has no experience with such activities.

On the cost side, our analysis assumes that the only cost of hiring a consultant is the commission charge. Lacking tract level data on consultant fees, our estimate of these fees is based on an average commission rate for consultants in North Carolina. Our cost estimates do not account for possible differences in charges (either in commission rates or in levels of fixed charges that may be levied in some instances) across tracts. Neither do they include the search costs to the landowner associated with locating a consultant, any costs that might be borne by the landowner in monitoring the activities of the consultant for the purpose of increasing the likelihood that the consultant is acting in his interest, nor the costs of determining the likely effect that a consultant will have on the price of a particular tract.

Keeping these limitations in mind, the results from Version 2 in Table 4 provide strong statistical evidence that the benefits from hiring a consultant increase with the volume of pine sawtimber per acre on a tract and somewhat weaker evidence that the benefits increase with the volume of hardwood sawtimber. The coefficient estimates from this regression are used in the following to obtain further insights into the benefits and costs associated with hiring a consultant.

The implied benefits of hiring a consultant, as a function of the volume of pine and hardwood sawtimber on a tract, are

$$B = -9.82 + 20.53 \cdot VOLPSAW + 14.19 \cdot VOLHWSAW, \qquad (14)$$

where -9.82 is the benefit (implied by the coefficient estimates in Version 2 of Table 4) of hiring a consultant on a tract with no pine or hardwood sawtimber, and the sample average volumes of the other types of timber.

The implied costs of hiring a consultant are

$$\begin{aligned} C &= 0.083[151.98 + (131.82 + 20.53) \cdot VOLPSAW + (77.60 \\ &\quad + 14.19) \cdot VOLHWSAW] \\ &= 12.61 + 12.65 \cdot VOLPSAW + 7.62 \cdot VOLHWSAW, \qquad (15) \end{aligned}$$

where 0.083 is the average commission rate, 151.98 is the predicted selling price of a tract of timber with no pine or hardwood sawtimber and the sample average values of all the other explanatory variables, and 131.82 ± 20.53 = 152.35 and 77.60 + 14.19 = 91.79 are the estimated values of additional pine and hardwood sawtimber on consultant-involved tracts. The corresponding implied net benefits ($B - C$) of hiring a consultant are

$$NETBEN = -22.43 + 7.88*VOLPSAW + 6.57*VOLHWSAW. \quad (16)$$

These estimates of net benefits, which we calculate for each sale in our sample, can be used to provide an additional validation test for our estimation results. Assuming that landowners are rational in their decision to hire a consultant, a positive correlation would be predicted between the net benefits of hiring a consultant and the likelihood of hiring one. To test this prediction (and the validity of our estimates), we calculate the correlation coefficient between the zero-one *CONSULT* variable and our estimates of net benefits. This correlation coefficient is positive and statistically significant at the 0.01 level. We also estimate a logit regression with *CONSULT* as the dependent variable and *NETBEN* as the explanatory variable. The estimated coefficient on *NETBEN* in this regression is positive and highly significant (asymptotic t-value = 4.1). We interpret these results as suggesting that our approach yields estimates of the net benefits of hiring consultants that are correlated with the estimates of these net benefits used by landowners in their decisions to hire a consultant.[22]

IV. CONCLUSIONS

Hedonic models have been widely used by economists to analyze the pricing of goods and resources with multiple attributes. Although it is clear that buyers and sellers do not have perfect information on all the attributes of such goods and resources, previous analyses using the hedonic model have assumed that perfect information exists. In this article, information services are included as an additional attribute, and several ways in which these services might affect prices are discussed. Using a highly detailed data set on prices paid for private timber tracts in North Carolina, empirical estimates are obtained of the value of the information provided by private timber consultants. These estimates demonstrate that consultants have positive and significant effects on timber prices. A comparison of simple OLS parameter estimates with estimates obtained using an approach that corrects for sample selection bias and allows for differences in error structures across buyers of different sizes suggests that the OLS estimates substantially overstate the impact of consultants on timber prices.

[22] If the actual net benefits of hiring a consultant magically became available, then the prediction would be that consultants would be hired on those sales for which the net benefits of hiring a consultant are positive. Given the discussion above, however, of the limitations associated with our estimates of the benefits and costs of hiring a consultant, such a prediction almost certainly imposes unreasonable demands on both our data set and our method of analysis. In fact, in our data sample, a reassuring 76% of the 139 sales with negative estimated net benefits did not hire consultants. Only 45% of the 159 sales with positive expected net benefits, however, did hire consultants. The latter result likely indicates that our approach underestimates the economic costs of hiring consultants on these sales.

Two different validation tests on our results provide support for the approach we use to estimate the impacts of consultants on timber sale prices. The first test indicates that the estimated effects of consultants are sensible from a market perspective—on average, consultants tend to charge fees that reflect the value of their services. The second test suggests that estimates of the net benefits of hiring a consultant derived from our estimated regression model are correlated with the estimates of these net benefits used by landowners when deciding whether to hire a consultant.

LITERATURE CITED

ANDERSON, W.C. 1969a. Determinants of southern pine pulpwood prices. USDA For. Serv. Res. Pap. SO-44. 10 p.

ANDERSON, W.C. 1969b. Pine sawtimber price behavior in South Carolina. USDA For. Serv. Res. Pap. SO-44. 12 p.

BARTIK, T.J., and V.K. SMITH. 1987. Urban amenities and public policy. *In* Handbook of regional and urban economics. Vol. 2. E.S. Mills (ed.) Amsterdam, North Holland.

BARZEL, Y. 1982. Measurement cost and the organization of markets. J. Law Econ. 25(1):27–48.

BOX, G.E.P., and D.R. COX. An analysis of transformations. J. Roy. Stat. Soc. (Series B): 211–243.

BRORSEN, B.W., W.R. GRANT, and M.E. RISTER. 1984. A hedonic price model of rough rice bid/acceptance markets. Am. J. Agric. Econ. 66(2):156–163.

FOLLAIN, J.R., and E. JIMENEZ. 1985. Estimating the demand for housing characteristics: A survey and critique. Reg. Sci. Urban Econ. 15(1):77–107.

FREEMAN, A.M. III. 1979. The benefits of environmental improvement. Johns Hopkins Press, Baltimore.

FRENCH, K.R., and R.E. MCCORMICK. 1984. Sealed bids, sunk costs, and the process of competition. J. Bus. 57(4):417–441.

GREENE, W.H. 1990. Econometric analysis. MacMillan, New York.

GRILICHES, Z. (ed.). 1971. Price indexes and quality change. Harvard University Press, Cambridge.

HARDIE, I.W., and R.C. WIELAND. 1987. Seller practices and sales return in local stumpage markets. P. 63–78 *in* Proc. 1987 Joint Meet. of the Southern For. Econ. Workers and the Mid-West For. Economists.

HAUSMAN, J.A. 1978. Specification tests in econometrics. Econometrica 46(11):1251–1271.

HECKMAN, J.J. 1979. Sample selection bias as a specification error. Econometrica 47(1):153–161.

HOLLEY, D.L. 1970. Factors in the 1959–69 price rise in southern sawtimber analyzed. For. Ind. (April):41–43.

HUBBARD, W.G., and R.C. ABT. 1989. The effect of timber sale assistance on returns to landowners. Resour. Manage. Optim. 6(3):225–234.

JACKSON, D.H. 1987. Why stumpage prices differ between ownerships: A statistical examination of state and Forest Service sales in Montana. For. Ecol. Manage. 18:219–236.

JACKSON, D.H., and A.G. MCQUILLAN. 1979. A technique for estimating timber value based on tree size, management variables and market conditions. For. Sci. 25(4):620–626.

JOHNSON, R.N. 1979. Oral auction versus sealed bids: An empirical investigation. Natur. Resour. J. 19(2):315–335.

JUDGE, G.C., W.E. GRIFFITHS, R.C. HILL, H. LUTKEPOHL, and T. LEE. 1985. The theory and practice of econometrics. Ed. 2. Wiley, New York.

KRONRAD, G.D., and C.A. ALBERS. 1983. Consulting forestry services and fees in North Carolina. Nat. Woodl. 7(1):9–12.

LARSON, D.M., and I.W. HARDIE. 1989. Seller behavior in stumpage markets. Land Econ. 65(3):239–253.

LEE, L. 1979. Identification and estimation in binary choice models with limited (censored) dependent variables. Econometrica 47(4):977–996.

LEFFLER, K.B., and R.R. RUCKER. 1991. Transaction costs and the efficient organization of production: a study of timber-harvesting contracts. J. Polit. Econ. 99(5):1060–1087.

MILGROM, P. 1989. Auctions and bidding: A primer. J. Econ. Persp. 3(3):3–22.

MUNN, I.A. 1993. Forestry consultants: Their effect on timber sales prices. Ph.D. diss. North Carolina State University, Raleigh.

NORTH CAROLINA STATE UNIVERSITY. Undated. The probit procedure. Div. of Econ. and Bus., Comput. Inf. Serv., SAS Library.

PALMQUIST, R.B. 1984. Estimating the demand for characteristics of housing. Rev. Econ. Stat. 66(3):394–404.

PALMQUIST R.B. 1989. Land as a differentiated factor of production: A hedonic model and its implications for welfare measurement. Land Econ. 65(1):23–28.

PUTTOCK, G.D., D.M. PRESCOTT, and K.D. MEILKE. 1990. Stumpage prices in southwestern Ontario: A hedonic function approach. For. Sci. 36(4):1119–1132.

RAO, P., and R.L. MILLER. 1971. Applied economics. Wadsworth Publishing, Belmont, CA.

ROSEN, S. 1974. Hedonic prices and implicit markets: product differentiation in pure competition. J. Polit. Econ. 82(1):34–55.

RUCKER, R.R. 1984. An economic analysis of bidding and cutting behavior on public timber sale contracts. Ph.D. diss. University of Washington, Seattle.

SAS. Tech. Rep. P-229. Changes and Enhancements—Release 6.07. 1992. SAS Institute Inc., Cary. P. 287–366.

STEELE, R.G.D., and J.H. TORRIE. 1980. Principles and procedures of statistics: A biometrical approach. Ed. 2. McGraw-Hill, New York.

STIGLER, G. 1961. The economics of information. J. Polit. Econ. 69(3):213–225.

THURMAN, W.N. 1986. Endogeneity testing in a supply and demand framework. Rev. Econ. Stat. 4(11):638–646.

VEEMAN, M.M. 1987. Hedonic price functions for wheat in the world market: Implications for Canadian wheat export strategy. Can. J. Agric. Econ. 35(3):535–552.

WILSON, W.W. 1984. Hedonic prices in the malting barley market. West. J. Agric. Econ. 9(1):29–40.

WU, D. 1973. Alternative tests of independence between stochastic regressors and disturbances. Econometrica 41(7):733–750.

1989 BUYERS OF FOREST PRODUCTS IN NORTH CAROLINA. 1989. North Carolina Dep. Environ., Health and Natur. Resour., Div. of For. Resour. 70 p.

APPENDIX: SAMPLE SELECTION BIAS

A major concern for the survey data is sample selection bias. This involves two questions. First, are certain segments of the buying population (for example, loggers versus dealers) more likely to participate in the survey than others? If so, the sample selection may be biased. However, this type of bias is not necessarily a problem. The second question is the key. Did those segments of the population that were over, or under, represented in the sample pay different prices for tracts of timber, holding the hedonic characteristics constant? If the answer is yes to both questions, then sample selection bias is a concern.

A technique that tests both of these questions and makes the appropriate adjustments to the regression estimates is provided by Heckman (1979), Lee (1979), and Greene (1990). Briefly stated, the procedure treats the bias resulting from nonrandom samples as a model specification error. Consider the following two equation models:

$$Y_i = \beta X_i + \epsilon_i \quad (1)$$
$$R_i = \alpha Z_i + \mu_i \quad (2)$$

where Equation (1) is the equation of interest, and Equation (2) models the selection bias. A potential member of the sample chooses to participate only if $R \geqslant 0$. If $R < 0$, no information on Y is provided. If selection bias exists, then the expected value of Y is

$$E[Y_i/X_i, R_i \geqslant 0] = \beta X_i + E[\epsilon_i/\mu_i \geqslant -\alpha Z_i] \quad (3)$$

The last term is equal to $[\sigma_{12}/(\sigma_{22})^{1/2}]\lambda_i$ where $\lambda_i = \phi(\alpha Z_i)/\Phi(-\alpha Z_i)$, σ_{22} is the variance of μ, and σ_{12} is the covariance of ϵ and μ. ϕ and Φ are the density and distribution functions for a standard normal variable, respectively. λ_i, which is known as the inverse Mill's ratio, is a monotonic decreasing function of the probability that an observation is selected. See Heckman (1979) for a complete description of this derivation. An inverse Mill's ratio can be calculated for each buyer from the regression results for Equation (2). By including the inverse Mill's ratio as an additional explanatory variable, consistent coefficient estimates for Equation (1) can be derived.

Including the inverse Mill's ratio in the regression introduces heteroskedasticity into the model. Although the parameter estimates will be unbiased, the OLS estimate of the covariance matrix will be inconsistent. The problem can be easily overcome in SAS's *PROC REG* procedure by specifying the option *ACOV* which produced the correct covariance matrix (SAS User's Guide: Statistics, p. 682).[23]

Application

A firm's probability of participating was modeled as a function of the segment(s) of the industry to which it belonged. The timber buying population was segmented on the basis of location, production capacity, type(s) of operation, and primary species utilized. The probability was estimated using maximum likelihood with a probit distribution function. The empirical model was:

$$P(\text{Reply}) = f(PD, MD, UCD, CD, S1DUM, S2DUM, S3DUM, S4DUM, S5DUM, LOG, DEALER, CONCYD, COMPBD, VENEER, PLYWOOD, SAWMILL, OTHER, PSYP, PHWD, PEWP, PMIS).$$

PD, MD, UCD, CD are dummy variables for the piedmont, mountain, upper coastal and coastal regions in the state. *CD* is the omitted variable.

LOG, DEALER, CONCYD, COMPBD, VENEER, PLYWOOD, and *SAWMILL* are dummy variables for loggers, dealers, concentration yards, composite board mills (particle and fiber), veneer mills, plywood mills, and sawmills, respectively. *OTHER* includes pallet mills, crosstie mills, portable sawmills, and treatment plants. Note that because firms can be horizontally or vertically integrated, these categories are not mutually exclusive. For example, one firm might consist of a logging crew, a concentration yard, and a dealership. Because these categories are not mutually exclusive, it is not necessary to omit one from the regression.

S1DUM through *S4DUM* are size dummies representing the firm's daily man-

[23] The printed standard errors and *t* values are still wrong, but the correct value can be computed from the covariance matrix.

ufacturing capacity. *S1DUM* represents firms whose daily production capacity is less than 10 mbf. *S2DUM* are firms whose capacity lies between 10 and 20 mbf, *S3DUM,* those between 20 and 50 mbf and *S4DUM,* those over 50 mbf. *S5DUM* represents buyers with no manufacturing capacity. Loggers and dealers are two examples. *S5DUM* is the omitted variable.

PSYP, PHWD, PEWP, and *PMIS* are dummy variables representing the primary species a firm utilizes: southern yellow pine, hardwood (oak, yellow poplar, gum, or soft maple), eastern white pine, and miscellaneous species, respectively. The fifth and omitted category is those firms who did not list a primary species. It was assumed that these firms were flexible enough to handle any species. This category consisted primarily of loggers.

Data

The *1989 Buyers Guide of Forest Products in North Carolina* is the source of the information used to estimate the probability function. There are a total of 667 buyers listed in the guide. Many of the buyers listed in the guide indicated they did not buy standing timber. Some purchased only delivered timber. Others no longer purchased timber of any kind. These buyers were eliminated from the data set. Buyers whose letters were returned as nondeliverable and whose phone numbers were no longer in service were also dropped from the data set. The final data set included 537 observations.

Results

The results from the probit regression estimating the probability of buyers participating in the survey are presented in Table A1. The test statistic (−2.0) *LL RATIO,* is a chi-square statistic with 19 degrees of freedom. The estimated statistics, 61.35, is statistically significant at the 0.01 level. Therefore, the null hypothesis that the nonintercept coefficients are jointly zero is rejected. The estimated coefficients for two buyer categories are statistically significant. The parameter estimate for *LOG* was significant at the 0.05 level, indicating loggers are less likely to participate in the survey than nonloggers. The parameter estimates are terms in the probit function and provide no insightful interpretation. However, the derivative of the estimated probability function with respect to the variable of interest represents the change in the probability of response evaluated at the means of the independent variables. These derivatives are also presented in Table 4. The parameter estimate for *LOG,* −0.58, translates into a 0.018 reduction in the probability of participation if the buyer is a logger. Firms whose daily manufacturing capacity is greater than 50 mbf are more likely to participate in the survey than firms who do not have manufacturing capability. The parameter estimate for *S4DUM* is significant at the 0.01 level and translates into an 0.11 increase in the probability that a buyer will participate. No other parameter estimates are significant.

Based on the significant chi-square value for the model and the significant coefficients on two of the buyer population segments, it is evident that participation in the survey was not randomly distributed throughout the various segments of the population. Therefore, the inverse Mills ratio should be included in the hedonic model as a correction for sample selection bias, at least initially. A sig-

TABLE A1.

Probability function for survey participation by timber buyers in North Carolina.

Variable	MLE	t-value	Derivative of probability function
CONSTANT	−3.68	−0.47	−0.1313
PD	−0.18	−0.68	−0.0061
MD	−0.14	−0.35	−0.0045
UCD	0.06	0.21	0.0021
S1DUM	−2.61	−1.14	−0.0562
S2DUM	0.55	1.57	0.0312
S3DUM	0.46	1.32	0.0246
S4DUM	1.14	3.00***	0.1132
LOG	−0.58	−2.21**	−0.0184
DEALER	0.30	1.16	0.0135
CONCYD	0.19	0.49	0.0083
COMPBD	−0.34	−0.44	−0.0085
VENEER	−0.76	−1.11	−0.0131
PLYWOOD	0.26	0.43	0.0122
SAWMILL	−0.04	−1.16	−0.0137
PSYP	2.17	0.28	0.0894
PHWD	2.45	0.31	0.3341
PEWP	2.25	0.28	0.4456
PMIS	3.61	0.45	0.8955
(−2.0) LL RATIO = 61.35		df for χ^2 = 19	
No. of observations = 537		Two-tailed significance tests	
		*** significant at 0.01 level	
		** significant at 0.05 level	

nificant coefficient for the inverse Mills ratio indicates different segments of the timber buying population pay different prices for timber tracts, after controlling for other characteristics in the hedonic model. If the estimated coefficient is not significant, different segments of the timber-buying population do not pay different prices, and the inverse Mills ratio can be dropped from further regressions.

Manuscript received April 13, 1993

AUTHORS AND ACKNOWLEDGMENTS

Ian A. Munn is with the Department of Forestry, Mississippi State University 39762, and Randal R. Rucker is with the Department of Agricultural Economics and Economics, Montana State University, Bozeman, MT 59717-0292. Helpful comments and suggestions on earlier drafts were provided by Ian Hardie, Jay Sullivan, Ray Palmquist, seminar participants at the 1992 Annual AAEA meetings, the 1992 annual SEA meetings, Mississippi State University, the University of Florida, and Montana State University, and anonymous referees. Ann McDermed, Walter Thurman, and Marcia Gumpertz provided statistical assistance. Financial support for this research was provided by the Woodlot Forestry Research and Development Program at North Carolina State University and the Southeastern Forest Experiment Station, USDA Forest Service. Support for Rucker was provided by the Montana Agricultural Experiment Station, Bozeman, MT—Project #101088.