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STUMPAGE PRICES IN SOUTHWESTERN ONTARIO:
A HEDONIC FUNCTION APPROACH

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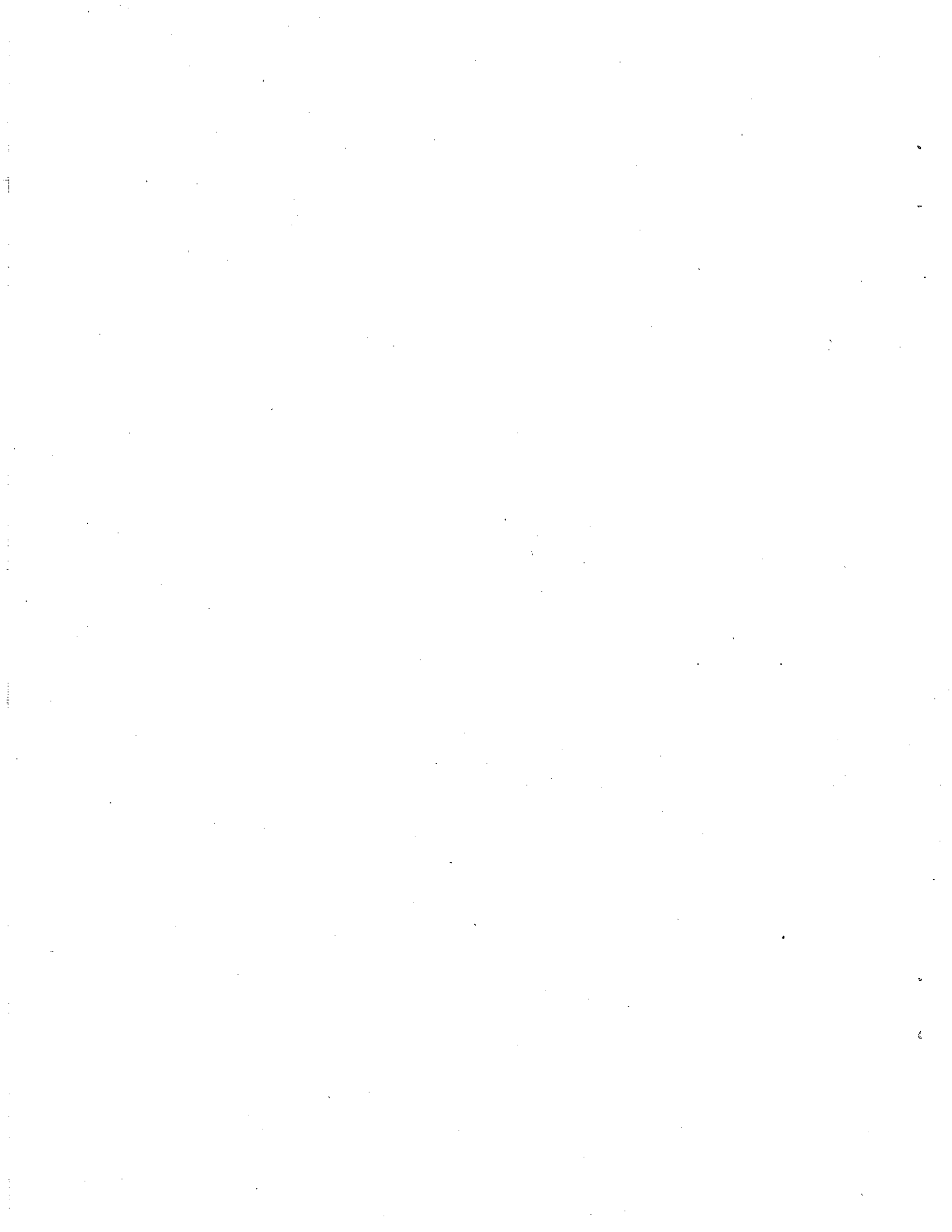Dept. of Agricultural Economics and Business
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ABSTRACT

Timber used in the production of lumber in Southwestern Ontario varies in a number of characteristics and the lump-sum stumpage price is expected to reflect differences in those characteristics. When heterogeneous inputs are used in production, the hedonic price function approach may be used to estimate marginal implicit values of the various input characteristics. Hedonic price functions have been estimated for timber in the region using pooled time-series cross-section data from a large sample of timber sales. The results indicate that volume, species composition, tree size, timber quality and distance to the purchasing mill will affect lump-sum stumpage prices. Estimates of the contributions that each of these characteristics makes to stumpage prices are presented.
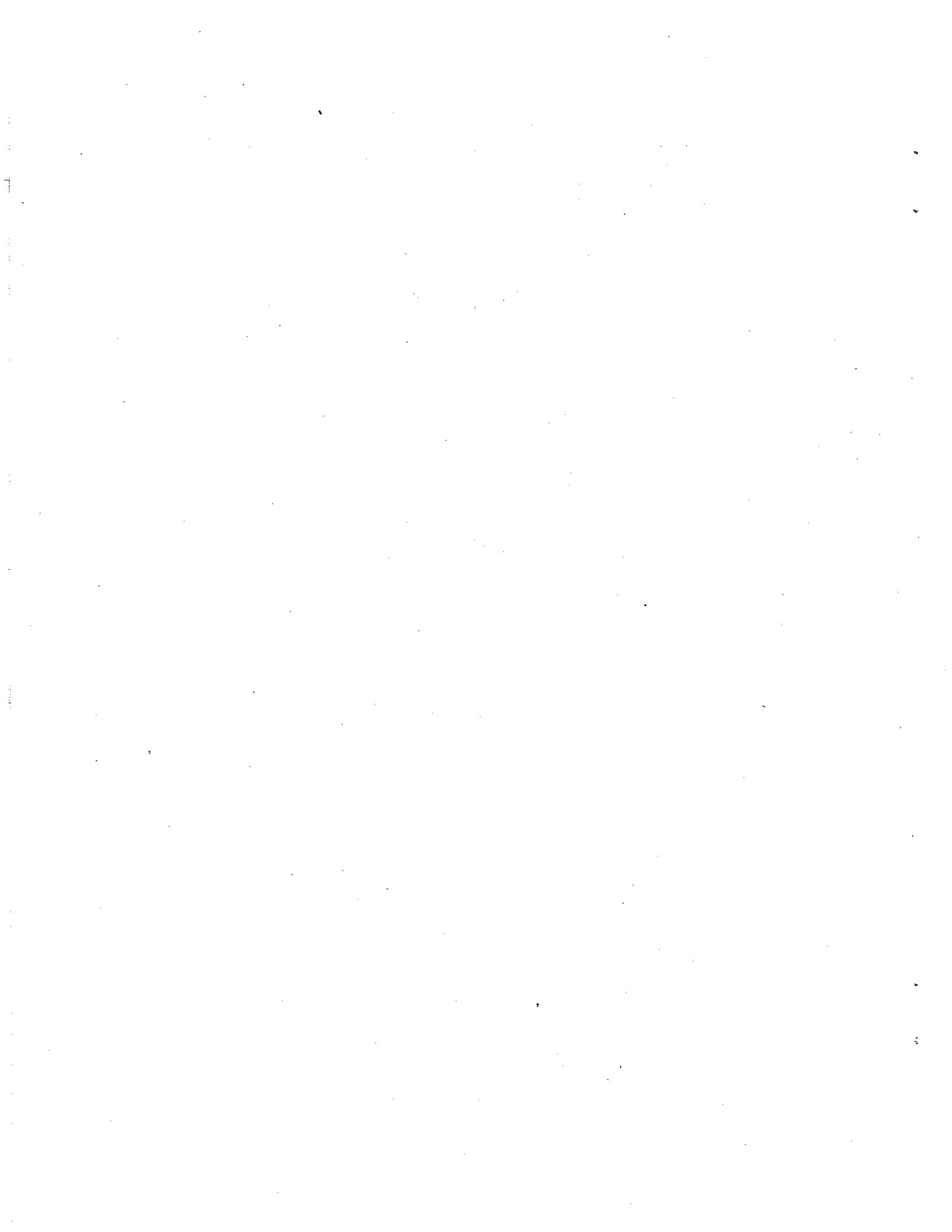
INTRODUCTION

The neoclassical theory of production assumes that individual factors of production are homogeneous and that profit maximizing firms will continue to purchase additional units of a factor until the marginal value product of that factor is equal to its price (Varian). This demand for factors of production is readily determined by the solution to the first order conditions for profit maximization.

However, some production inputs are heterogeneous and exhibit significant differences in their underlying production characteristics. Under these circumstances, a hedonic pricing approach can be used to estimate the implicit prices of the various characteristics of an input and subsequently the derived demand for that input (Ladd and Martin, 1976).

This is the case for timber used in the manufacture of lumber. The timber in a particular woodlot varies in species composition, quality and the size or volume of individual trees. The stumpage price or amount paid for the standing timber is expected to reflect these differences in its characteristics.

In Southwestern Ontario, where approximately 97% of the productive forest land is privately owned, the Ministry of Natural Resources provides an advisory service to landowners which includes stand marking, and advertising the marked timber to potential buyers. Buyers then negotiate directly with the woodlot owner for the sale of the timber. The Ministry usually provides the landowner with an estimated range of values for the marked timber in the woodlot, however there is no standard procedure followed in providing price estimates. This gives rise to the problem of asymmetric information and a woodlot owner may be at a considerable disadvantage when negotiating with timber buyers. A method of forecasting stumpage values based upon the characteristics of the timber in the stand would not only provide landowners with information about the value of their timber but also about the relative values of the various characteristics of the stand.

The purpose of this paper is to present a review of the theory and use of hedonic price functions and to apply the hedonic technique to estimating lump-sum stumpage prices in Southwestern Ontario.

THE HEDONIC PRICE FUNCTION

The hedonic price function was first predicated on the assumption that individuals derive utility from consuming the characteristics of a good, and it is these characteristics, rather than the good itself which are the arguments in the individual's utility function. The conditions for utility maximization result in a hedonic price function in which the price of a heterogeneous good is a function of the characteristics or attributes of that good (Lancaster 1966).

Early assessments of the problem of quality variation in consumer products and the theory of consumer behaviour were made by Houthakker (1952). Becker (1965), Lancaster (1966) and Muth (1966) later developed Houthakker's methods into household production theory. The theory was subsequently extended by Rosen (1974) to consider the competitive equilibrium of hedonic price functions.

The hedonic approach has also been used to estimate the demand (including derived demand) for the characteristics of a diverse group of goods including agricultural commodities (Brorsen et al. 1984, Jordan et al. 1985), housing (Linneman 1980, DeWees 1976, King 1976), land (Downing 1973, Chicoine 1981) and public goods such as outdoor recreation services (Sinden 1974) and fish and wildlife resources (Adamowicz and Phillips 1983).

The hedonic technique was adapted to apply to heterogeneous production inputs by Ladd and Martin (1976). Much of the empirical work in this context has focused on the characteristics of agricultural commodities as primary inputs in the production of food and beverage items (Wilson 1984, Veeman 1987) and fabrics (Ethridge and Neeper 1987).

When homogeneous inputs are used in production, the demand for factors of production is determined by the solution to the first order conditions for profit maximization.

For a single output, L, and input X, the profit function for a representative firm in a perfectly competitive market can be stated as:

$$\pi = P_L \cdot f(X) - P_x X. \tag{1}$$

The first order conditions for profit maximization with respect to input X are:

$$d\,\pi/dX = P_L\,(df/dX) - P_x = 0. \tag{2}$$

Solving for P_x gives

$$P_x = P_L \ (df/dX). \tag{3}$$

where (df/dX) is the marginal yield from the input in production of L. The term $P_L \ (df/dX)$ is the marginal value product of input X and expression (3) represents the factor demand for the input.

However, in the case of heterogeneous inputs such as timber, the total contribution of an input to production depends upon the amounts of the various characteristics it provides, and total production depends on the total amounts of all characteristics (Ladd and Martin 1976).

For a single output, L, the production function for a profit maximizing competitive firm can be depicted as:

$$q_L = F(V_1, \ V_2 \ldots V_m) \tag{4}$$

where q_L is the quantity of product L, and V_j is the quantity of input characteristic j $(j = 1 \ldots m)$. Expression (4) states that output depends upon the amounts of the various input characteristics used in production.

For simplicity, we assume that bundles of characteristics are purchased in units of X. For example, X could represent the size of a woodlot measured in terms of its area. The single input X is used in the production of product L, and P_L and P_x are the given prices of output L and input X respectively. It follows that the firm's profit function can be written as:

$$\pi = P_L \cdot F(V_1 \ldots V_m) - P_x \ X \ ; \ j = 1 \ldots m \tag{5}$$

The first order conditions for profit maximization are:

$$\frac{d\pi}{dX} = P_L \ \sum_j \ (\delta F/\delta V_j) \ (dV_j/dX) - P_x = 0. \tag{6}$$

Solving for P_x gives:

$$P_x = P_L \ \sum_j \ (\delta F/\delta V_j) \ (dV_j/dX) \tag{7}$$

where (dV_j/dX) is the marginal yield or contribution of input X to the jth characteristic used in production and $(\delta F/\delta V_j)$ is the marginal physical product from one unit of characteristic j. Thus $P_L \ (\delta F/\delta V_j)$ is the value of the marginal product of the jth characteristic of input X in producing L.

By assuming $(\delta F/\delta V_j)$ is constant, equation (7) can be

simplified by setting $(\delta F/\delta V_j) = \beta_j$.

Thus:

$$P_x = P_L \sum_j \beta_j (dV_j/dX). \qquad (8)$$

In addition, we make the usual assumption that the quantity of characteristic j is proportional to the number of units of X, that is $V_j = \theta_j X$ then the term,

$$(dV_j/dX) = \theta_j = \frac{V_j}{X} .$$

Thus expression (8) may be written as:

$$P_x = P_L \sum_j \beta_j \left(\frac{V_j}{X}\right) \qquad (9)$$

Multiplying through by X gives:

$$P_x X = P_L \sum_j \beta_j V_j \qquad (10)$$

In the case of standing timber which is purchased by a sawmill as an input to lumber production, let X be defined as the area of a woodlot expressed in hectares. Thus P_x is the stumpage price per hectare of the timber sale and $P_x X$ is the lump-sum stumpage paid for the marked timber in the woodlot.

Expression (10) states that the lump-sum stumpage associated with a particular woodlot is equal to the sum of the marginal value products, $P_L \beta_j$, of each characteristic times the total quantity of each characteristic, V_j, in that woodlot.

The usual hedonic method is to estimate the marginal physical products, β_j, of the input characteristics by regressing observed input prices on the quantities of the characteristics contained in the input, using the best fitting functional form. The linear form of equation (10) corresponds to the form of the hedonic price function derived by Lucus (1975), Ladd and Martin (1976) and others. However, a hedonic price equation is a reduced-form equation reflecting both supply and demand influences (Jordan et al, 1985). Consequently, the appropriate functional form cannot be specified on theoretical grounds (Rosen, 1974). Most investigators have settled after some experimentation for a semi-logarithmic or log-linear relationship between prices and characteristics (Lineman 1980, Adamowicz and Phillips 1983, Ethridge and Neeper 1987). Others favour a linear specification, partly because of its theoretical interpretation and ease of explanation to the respective industry (Brorsen et al 1984; Veeman 1987) while still others advocate the use of a

Box-Cox transformation to determine the optimal functional form (Anderson 1985; Jordan et al 1985). In this study, we fitted the model in both logarithmic and linear forms which are special cases of the Box-Cox transformation, and then determined which of the standard functional forms provided the best approximation.

DATA

The data for this study consists of pooled time-series cross-section information for a sample of 344 timber sales throughout Southwestern Ontario over the period 1982 to 1987 obtained from timber sales notices. Table 1 provides an example of the information for an individual sale.

Table 1. Example of timber sale data.

Owner and Address	Location	Remarks
xxxxx	Lot 21 Concession I Harwich Twp. Kent Cty. Chatham Dist.	Woodlot 8.8 hectares Quality Fair to Good Access Good Advertised 1987-01

Species	No. Trees	Average Vol/Tree (M³)	Estimated Volume (M³)
Red Oak	25	1.3	31.5
White Ash	29	1.0	28.0
Swamp White Oak	12	1.8	21.5
Hard Maple	116	1.6	182.0
Beech	114	1.1	129.0
White Pine	2	1.3	2.6
	298	1.3	394.6

Lump-Sum Stumpage Price   = $23,000

Purchasing Mill   =   xxx Lumber Inc.

Source: Ontario Ministry Natural Resources.

The timber sales notices provide information about the number of trees marked for harvesting, the estimated volume of each species and an estimate of the average quality of the marked trees. The area of

the woodlot, its accessability and location are also recorded. An estimate of the range of lump-sum values was also provided for 43 of the 344 timber sales used in the sample.

The information for individual tree species was aggregated into three species groups: (i) 'Q' hardwoods representing the higher valued hardwood species such as oak species (*Quercus* L.), ash species (*Fraxinus* L.), Black Walnut (*Juglans nigra* L.), Black Cherry (*Prunus serotina Ehrh.*) and Yellow Birch (*Betula lutea* Michx F.); (ii) 'H' hardwoods including the maple species (*Acer* L.), American Beech (*Fagus grandifolia Ehrh.*), White Birch (*Betula papyrifera* Marsh.) and all poplar species (*Populus* L.) and (iii) all softwood species.

Several other variables such as the number of trees and estimated volume per hectare were calculated from the primary information. Finally, each woodlot in the sample was graded according to a timber quality index which recognizes four categories:

Quality Index	Quality Description	Criteria (% by volume Grades 1&2 sawtimber)
1	Excellent	15% or greater
2	Good	10% - 15%
3	Fair	5% - 10%
4	Poor	less than 5%

The lump-sum purchase price for each woodlot and the name of the purchasing mill where available, were obtained from post-sale surveys conducted by the Ministry of Natural Resources. When the locations of the woodlot and purchasing mill were known, the hauling distance to the purchasing mill was calculated.

With the time-series data used, price differences over time must be taken into account. A common approach has been to account for temporal changes by including time as a dummy variable in the model (Ethridge and Neeper 1987, Veeman 1987). A second method of accounting for time is to use an index variable, as an independent variable (Deaton and Muellbauer), and this approach has been followed in the study. Average lumber prices were obtained for the species most frequently occurring using information from the Statistics Canada Census of Manufacturers for the years under consideration. A composite lumber price was then calculated for each woodlot based on the species composition in the stand using a geometric transformation.

$$PL_i = P^Q_L{}^{PCTQ_i} \quad P^H_L{}^{PCTH_i} \quad P^S_L{}^{PCTS_i} \, . \tag{11}$$

Expression (11) may be written as:

$$lnPL_i = lnPCTQ_i \, lnP^Q_L + PCTHi \cdot lnP^H_L + PCTS_i \cdot lnP^S_L \cdot$$

where:

PL_i = composite lumber price index for the ith woodlot,

P^j_L = average lumber price for the jth species group; (j = Q,H, softwood),

PCT_{ji} = proportion by volume of the jth species group in the ith woodlot; (j = Q, H, softwood) and,

ln indicates natural logarithm.

THE MODEL, ESTIMATION PROCEDURES AND RESULTS

There is evidence to suggest that the stumpage price paid for standing timber from a particular woodlot is affected by the characteristics of the timber in the stand as well as the attributes of the woodlot itself (Anderson 1976, Nautiyal 1982). Lumber is priced on the basis of species, grade and dimension. Therefore, characteristics of the timber such as the quality and size or volume of individual trees which are likely to affect the yield and grade of lumber produced, are expected to influence stumpage prices. There may also be differences in lumber yield associated with different species or species groups which will affect not only the volume of lumber recovered from logs of a particular species but also the volume and marketability of by-products such as pulp chips or fuelwood. Thus the species composition in a particular woodlot may affect both the yield and value of lumber and by-products recovered from the timber in the woodlot and thereby affect stumpage prices.

Attributes of the woodlot such as its accessibility and distance from the purchasing mill will affect the costs of harvesting, transporting and processing of the timber from the woodlot. Thus the stumpage value of the timber may be viewed as a residual after deducting harvesting, transportation, and processing costs, plus an allowance for profit and risk, from the selling price of the lumber and by-products of the lumber manufacturing process.

Considering these factors, the empirical model is specified as:

$$lnPX_i = \beta_0 + \beta_1 \, lnTVOL_i + \beta_2 \, lnPCTQ_i + \beta_3 \, lnPCTH_i + \beta_4 \, lnVPL_i$$
$$- \beta_5 \, lnQAL_i - \beta_6 \, lnDIST_i + \beta_7 \, lnPL_i + e_i \qquad (12)$$

where:

PX_i = lump-sum stumpage price of the ith woodlot,

$TVOL_i$ = total estimated volume in the ith woodlot,

$PCTQ_i$ = proportion by volume of the Q species group

in the ith woodlot,

$PCTH_i$ = proportion by volume of the H species group in the ith woodlot,

VPL_i = average volume per tree in the ith woodlot,

QAL_i = quality index for timber in the ith woodlot,

$DIST_i$ = hauling distance from the ith woodlot to the purchasing mill,

PL_i = composite lumber price index for timber from the ith woodlot,

e_i = residual, and

ln indicates the natural logarithm.

The model as specified in (12) was estimated using ordinary least squares. The model is also fitted using a linear functional form and a Box-Cox transformation of the form:

$$(PX^{\alpha}_L - 1)/\alpha = A + \sum_{j=1}^{m} \beta_{ji} \; [(V^{\alpha}_{ji} - 1)/\alpha] \; . \qquad (13)$$

where:

PX^{α}_L = lump sum stumpage price,

V^{α}_{ji} = jth characteristic for the ith woodlot; $(j = 1...m)$,

α = exponent on the dependent and explanatory variables; $(-1 \leq \alpha \leq 1)$.

Before examining the empirical results, consider first the signs that we expect each coefficient to have. The coefficients of total volume (TVOL), average volume per tree (VPL) and lumber price index (PL) are unambiguously expected to be positive. An increase to one or all of these variables is expected to result in a higher stumpage price for the woodlot.

The quality index varies from 1 for excellent quality timber to 4 for timber considered to be of poor quality. Thus the expected sign on quality is negative since poorer quality levels result in lower stumpage prices. The expected sign on hauling distance is also negative since longer distances mean greater transportation costs thereby reducing the value of the timber.

An increase in the proportion by volume of the Q species group in a particular woodlot is expected to have a positive effect on its value. Hardwood lumber of these species is usually

priced higher than lumber of other species. During the period 1982 to 1987 represented in the model, hardwood lumber from the H species group generally brought higher prices than did softwood lumber. Thus we would expect $\beta_2 > \beta_3 > 0$.

The coefficient, β_7 is always expected to be positive since an increase in the composite lumber price index will eventually result in higher timber values. The estimation results are presented in Table 2.

Table 2. Estimates of the Hedonic Price Function for Standing Timber in the Southwestern Timber Supply Area, 1982 - 1987. OLS Procedure.

					Estimated Coefficients and Associated t-Statistics[a]						
Intercept β_0	Total Volume β_1	Percent Q spp. β_2	Percent H spp. β_3	Vol/ Tree β_4	Quality Index β_5	Hauling Distance β_6	Price Index β_7	Adjusted[b] R^2	F Statistic	No. Obs.	α
				- LOGARITHMIC FUNCTIONAL FORM -							
-1.31 (-0.84)	0.94 (37.86)	0.03 (2.08)	0.05 (1.75)	0.26 (4.27)	-0.26 (-4.68)	-0.10 (-4.62)	1.21 (3.94)	0.843	263.9[c]	344	0
				- LINEAR FUNCTIONAL FORM -							
-7393.5 (-1.87)	42.85 (40.69)	4207.1 (2.62)	2818.5 (1.79)	2699.5 (3.57)	-1138.7 (-4.27)	-16.94 (4.42)	38.32 (1.90)	0.853	285.6[c]	344	1
				- BOX-COX TRANSFORMATION VERSION -							
-7.03 (-1.60)	1.73 (39.43)	1.83 (3.02)	1.54 (2.61)	1.21 (4.63)	-0.95 (-4.74)	-0.24 (-4.86)	1.76 (3.25)	0.853	284.5[c]	344	0.16

a t-statistics are in brackets
b Adjusted for degrees of freedom
c F-statistics significant at the 99% level of significance

DISCUSSION OF RESULTS

With reference to Table 2, the parameter estimates for all variables are of the correct *a priori* sign. All coefficients, except those on the percent of H species (PCTH) in the logarithmic and linear functional forms and the composite lumber price index (PL) in the linear functional form, are significantly different from zero at the 95 percent level.

The adjusted R^2 is approximately 0.85 for all functional forms of the model and the F-statistics are all significant at the 99 percent level.

A likelihood ratio test was performed to test for significant differences between the three functional forms. The results suggest that the value of $\alpha = 0.16$ from the Box-Cox transformation is not significantly different from zero at the 99 percent level of confidence but α is significantly different from 1 at the same confidence interval. Thus it may be concluded that the logarithmic functional form is more appropriate for estimating the model than the linear form.

The results are plausible and consistent with *a priori* expectations. The estimated coefficients are interpreted as the marginal implicit prices for the woodlot characteristics and are also used to estimate the elasticity or qualitative measure of the resonsiveness of the lump-sum stumpage price to changes in the level of the various characteristics. For example, in reference to the estimated coefficients from the logarithmic functional form, a one percent increase in total volume and the average volume per tree will result in a 0.94 percent and 0.26 percent increase in the lump-sum price respectively. Figure 1 demonstrates the effect on the lump-sum price of a change in the proportion by volume of the Q hardwood species group for woodlots varying in volume from 100 to 300 cubic meters.

The results also suggest that timber quality (quality measured inversely) and hauling distance to the purchasing mill are both characteristics which significantly affect the stumpage price for timber in a particular stand. For a woodlot with a given set of characteristics and timber quality, an increase in hauling distance of 50 kilometers will reduce the stumpage received by the woodlot owner by approximately $847, (Fig. 2). This reduction in stumpage value would be more than offset if the quality of the timber in the stand was improved since, for a stand with given characteristics and location, the marginal value of an improvement in timber quality is approximately $1,138.

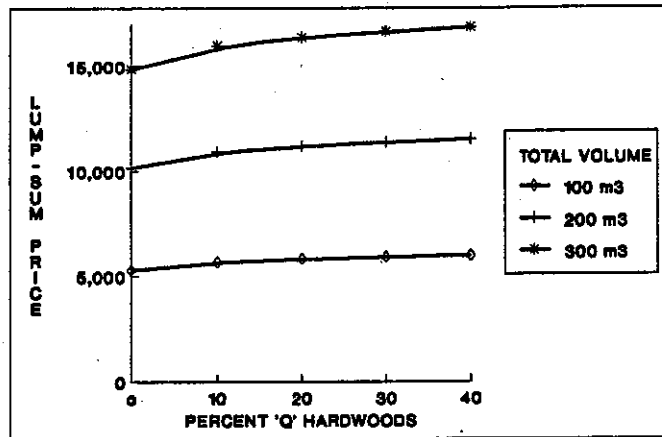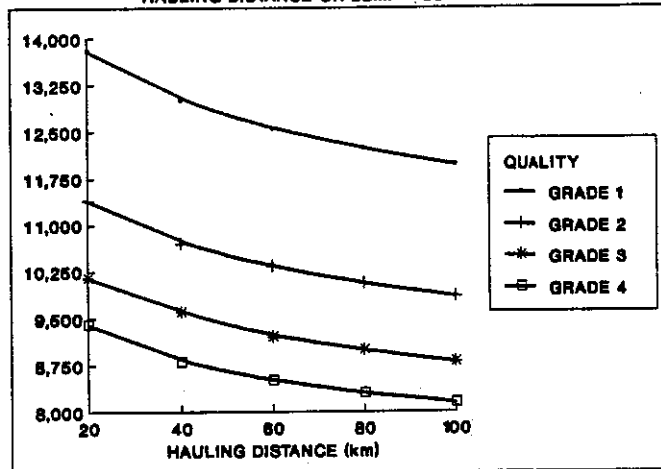**FIG1. EFFECTS OF PERCENT 'Q' HARDWOODS
ON LUMP-SUM PRICE**

**FIG2. EFFECTS OF TIMBER QUALITY AND
HAULING DISTANCE ON LUMP - SUM PRICE**

PREDICTING STUMPAGE PRICES USING THE MODEL

The preceding discussion has demonstrated the effects of each of the stand characteristics on the stumpage price. It remains, therefore, to determine whether the model could be used to reliably predict lump-sum stumpage prices. To provide a point of comparison, the model forecasts are evaluated against those of the Ministry of Natural Resources. The Ministry usually provides the landowner with an estimate of the minimum amd maximum of values of timber in the woodlot. The comparison is accomplished by estimating the lump-sum stumpage prices using the model for a sample of 43 woodlots and regressing the predicted prices on the actual prices received by the landowners. It should be noted that these woodlots were not included in the data used to estimate the model. These results are then compared to those obtained when the Ministry estimates for the same sample of woodlots are regressed on actual prices.

The results of the comparison are indicated in Table 3. The estimated values of the intercept, β_0 and the coefficient β_1, are expected to be 0 and 1 respectively. The results suggest that the estimate of these coefficients for the regressions on the maximum and average price as estimated by the Ministry achieve *a priori* expectations at the 95% level of significance. However the estimated values of β_0 and β_1 from the regression on the minimum price as estimated by the Ministry and the predicted values from the model are significantly different from 0 and 1 respectively at the 95% level of significance.

The results of the comparison suggest however, that the model can be reliably used to predict lump-sum stumpage prices in Southwestern Ontario and is superior to the method used by the Ministry when estimating lump-sum prices for the sample of 43 woodlots as judged by the adjusted R^2. However, the results also indicate that the Ministry estimates are reasonably accurate, particularly when the average of the Ministry price range is used.

Table 3. Regressions of Estimated Price on Actual Price. OLS Procedures

	Estimated Coefficients and t-Statistics[a]				
Explanatory Variable	Intercept β_0	Estimated Price β_1	Adjusted[b] R^2	F Statistic	No. of Observations
Predicted	$- 1.16$ (-2.35)	1.12 (20.67)	0.91	427.3[c]	43
Estimated Minimum	1.84 (3.21)	0.82 (12.58)	0.79	158.2[c]	43
Estimated Maximum	1.03 (1.44)	0.89 (11.21)	0.75	125.6[c]	43
Estimated Average	0.87 (1.42)	0.91 (13.27)	0.81	176.2[c]	43

a   t-statistics are in brackets
b   Adjusted for degrees of freedom
c   F-statistics significant at the 99% level of significance

CONCLUSIONS

The hedonic pricing approach has been used to estimate lump-sum stumpage prices for timber in Southwestern Ontario. Although a number of functional forms were used to estimate the model, the logarithmic form was shown to provide the most accurate estimates.

The estimated coefficients on the stand characteristics variables may be interpreted as the marginal implicit prices of those characteristics. Landowners are receiving a premium for hardwood timber species, particularly for the species in the Q hardwoods group. A premium is also paid for larger timber as given by the average volume per tree. Timber quality and distance to the purchasing mill are also characteristics of a woodlot which influence the stumpage price received by the landowner.

The model was used to predict lump-sum stumpage prices in the region and appears to be a superior method for estimating stumpage prices than the method currently used by the Ministry of Natural Resources.

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