Hedonic Valuation of Timber Stands in the Great Lakes Northern Forests

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A PLAN B PAPER
Submitted to

Michigan State University
in partial fulfillment of the requirements
for the degree of
Master of Science

Agricultural, Food and Resource Economics

2010

Abstract

Forests and timber are important natural resources in the state of Michigan. Forestlands make of 53% of the total land area and the forest related industry and manufacturing sector in Michigan generate approximately $12 billion to the state's economy.

Though forestry related industry and manufacturing is a multi-billion dollar industry that affects millions of acres of land in Michigan, there have been few recently published articles regarding timber stumpage appraisal in the state particularly about the northern hardwood forests. This paper uses a hedonic timber stumpage appraisal model to calculate stumpage value for state managed forests. The model uses data from Michigan Department of Natural Resources to estimate the affect of various parameters on the accepted bid of public timber sales. From our results we found there were certain parameters that were statistically significant in raising the final bid price of a sales and this may have implications for the management of state owned forest lands.

Acknowledgements

This paper would not have been possible without the guidance and support of my committee, Dr. John Hoehn, Dr. Michael Walters, and Dr. Frank Lupi. I especially want to thank Dr. Lupi for his encouragement and patience with me throughout this process.

I also want to thank Dr. Jack Liu, Dr. Kim Hall, Dr. James Millington and Megan Matonis at the Center for Systems Integration and Sustainability for allowing me to pester them with questions on the biological aspects of our project and for showing me the beauty of Michigan's wilderness. Research is impossible without data, and for that I would like to thank Douglas Heym from the Department of Natural Resources for providing me with the data set on which this paper is based.

Finally, I would like to thank all my friends and family for their support and to Dave for sticking by while I was thousands of miles away.

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Agricultural Economics MS Plan B Paper

Revised: March 23, 2010

1. Introduction

Forests and timber are important natural resources in the state of Michigan. Forestlands make of 53% of the total land area of Michigan and consist of approximately 19 million acres of land. The forest related industry and manufacturing sector in Michigan generate approximately $12 billion to the state's economy while forest-related tourism and recreation contribute $3 billion. The industry also provides 20,000 jobs related to forestry and forestlands (MiDNR 2008). As an intermediate input, timber from state owned forests provide the raw material for many of the saw and pulp mills in the state (MiDNR 2008). Logging and harvesting are also important tools used by forest managers to maintain ecosystem integrity and services. For example, the Department of Natural Resource's (DNR) forest service may obtain bids from logging firms to clear-cut a hardwood forest and convert it into a pine plantation or to perform a salvage cut on a hardwood forest stand to remove pest ridden trees for a healthier forest and ecosystem.

The geographic characteristics of the Great Lakes area, including the state of Michigan, have been greatly shaped by a legacy of glaciers with melting waters from glaciers filling the Great Lakes basins, creating one of the world's largest freshwater resources and ecosystems (Smith 1995). Northern hardwood and northeastern conifer forests are the two main forest types found in this area, and they range from Minnesota and the western Great Lakes to New England and the western Ontario (Mladenoff and Pastor 1993). The dominant forest type in Michigan is northern hardwood forest, and some of the species found in these forests are sugar maple, red maple, basswood, beech, and yellow birch. However, northern hardwoods were not always the dominant forest type and are considered a successional forest to conifer forests (Gates, Clarke et al. 1983). The conifer forests that were predominant before northern hardwood succession were northeastern conifer forests, and this forest type includes hemlock, balsam fir, white/red spruce, white pine, and jack pine (Smith 1995). White pine is a particularly valuable species for timber, and according to Ahlgren and Ahlgren (1983), "lumbering" referred exclusively to the harvest of white pine before the species became scarce under extensive harvesting around the middle of the century.

The utilization of Michigan's forestlands through harvesting and converting land into tillable farmland has made a lasting impact on the forest regions of the area (Ahlgren and Ahlgren 1983). Logging of old growth forests in the 1800s and early 1900s provided ideal conditions for aspen stands (Dickmann and Leffers 2003), and the harvest of conifers paved the way for northern hardwood forests. Even with human involvement of forestlands, the forests in Michigan are still home to a wide variety of wildlife (Gates, Clarke et al. 1983).

Though forestry related industry and manufacturing is a multi-billion dollar industry that affects millions of acres of land in Michigan, there have been few recently published articles regarding timber stumpage appraisal in the state particularly about the northern hardwood forests. Timber stumpage appraisal is concerned with estimating the value of standing trees—also known as stumpage—before they are harvested. This paper uses a hedonic timber stumpage appraisal model that has shown up in the forestry economics literature as timber transaction evidence appraisal (Leefers 2006; Niquidet and van Kooten 2006) method for coming up with a stumpage value for state managed forests.

Even though there are papers and published articles on timber appraisal methods, this paper fills the gap in the literature in at least two ways. First, our study provides an update on timber stumpage appraisal for Michigan's state managed forestlands. It is important both for forest managers and loggers to have an accurate estimation of the implicit prices of forest stand characteristics as it can help them make better decisions in the bidding process. Secondly, our model estimates stumpage values for northern hardwood forests in Michigan. In our literature review of published papers there were no articles in the past decade that dealt with timber stumpage appraisal for northern hardwood forests in the region. This may be due to the heterogeneous characteristic of northern hardwood forests that make these stands more difficult to appraise (Dickmann and Leffers 2003). In addition, the DNR dataset used in this paper is much larger than many of the datasets in the literature and allows us to have enough observations to estimate implicit prices for the complex mix of species found in northern hardwood forests.

Finally, in addition to filling gaps in the stumpage appraisal literature, the model presented in this paper can be modified for further use in our project's forest ecology and economics project. We are studying a forest area in Michigan's Upper Peninsula (Figure 1) to understand the interaction of ecological and economic effects of deer herbivory on forest stand structure and tree recruitment and how changing forest landscapes affect migratory bird habitat. One of the project's goals is to create a model of forest ecology and economics interaction of the study area. To accomplish this, we need a model for valuing the timber that can be provided by a stand. By considering the many characteristics of Michigan's forest stands, this stumpage appraisal model will fill gaps in the literature regarding stumpage appraisal in the state and also help forest managers understand the tradeoffs of different management scenarios.

2. Literature Review

2.1 Forest Stand Valuation

The literature on when stumpage should be harvested to maximize volume of timber or economic returns to investment is vast (Newman 2002). The Faustmann model is perhaps the most well known economic model of timber rotations. Whereas previous models focused on the biophysical aspects of tree growth and harvest, the Faustmann model incorporated land use value by accounting for perpetual timber rotations. However, application of the Faustmann model to a multi-use or ecosystem management plan of forestry is limited since the Faustmann model is concerned with only a single stand and does not consider intensive and extensive use of forestland or the multi-use characteristics of several forest stands (Yin and Newman 1997).

Another form of timber valuation uses options value to take into consideration risk, uncertainty, and irreversibility of timber harvest (Reed 1993; Yin 2001). Options valuation of timber stands is a useful tool to help forest managers determine when they should harvest to maximize returns when dealing with fluctuations in prices or risk from natural disasters such as fire or pest and incorporates the irreversibility of timber harvest and thus the non-timber uses of a forest. An asset sale price or reserve price also helps forest managers account for uncertainty in timber prices (Brazee and Mendelsohn 1988). However, in both the Faustmann and options value model for timber valuation, it is necessary to assign a price for stumpage in order to accomplish the valuation calculations. To that end, this paper can provide the stumpage prices necessary to complete calculations for other economic methods of forest management and valuation.

2.2 Stumpage Appraisal Methods

The literature contains several examples of timber appraisal methods. The United States Forest Service uses a residual value method of timber appraisal. The residual value method takes into account what the average logging firm would make from a harvest by predicting the value of the products from the harvest, subtracting the costs incurred by the firm from harvesting and converting harvests into the products sold to the mill (Wiener 1981; Schuster and Niccolucci 1990). The difference between the firm's cost and revenue is what the forest service would charge the firm for the right to harvest the stand. Another method that is used to appraise timber is the transaction evidence appraisal method. The transaction appraisal method uses the bids from previous sales to predict the bids of future stands with similar characteristics. The transaction evidence appraisal method--a regression analysis approach—also uses hedonic pricing theory to estimate existing stumpage prices by using implicit prices or the marginal values of characteristics to derive the value of the stand (Niccolucci and Schuster 1994; MacKay and Baughman 1996; Niquidet and van Kooten 2006). Transaction evidence appraisal can help timber analysts understand the market in which timber is being sold at by examining whether timber is being priced competitively (Niquidet and van Kooten 2006).

Most of the timber appraisal publications examined in the literature review used a multiple regression analysis to estimate timber stumpage (Schuster and Niccolucci 1990). This transaction evidence approach has also been described as a hedonic timber stumpage appraisal model (Leefers 2006; Niquidet and van Kooten 2006). Different variations on the transaction evidence appraisal method appear in the literature. Buongiorno and Young (1984) used a stepwise regression approach. Their study used a dataset of 101 observations from the Chequamegon National Forest in northern Wisconsin from 1976 to 1980. Sixty-five variables were considered and the stepwise procedure they adopted reduced the linear model to 14 variables that explained 93% of the variance in high bid for their data. A weighted database approach was used by Niccolucci and Schuster (1994). In the study, the authors experimented with different database lengths (the number of years of sales in their database) by using one to three years of sales observations and giving more "weight" to recent sales to estimate a stumpage appraisal model that was more responsive to market changes. The data used in their study came from national forests in the Northern Region of the US Forest Service from October 1984 to March 1991, and their models used between 200 to 750 observations.

As mentioned in the introduction, there were only a few timber appraisal articles using data from the Great Lakes area (Buongiorno 1984; Puttock 1990; MacKay and Baughman 1996) with one article that was published in the past three years (Leefers 2006). MacKay and Baughman's analysis was done on Minnesota state forests sales in 1991. Puttock et al.'s (1990) article used a hedonic approach to estimate stumpage prices in Southwestern Ontario. The study used a sample of 344 timber sales over the period of 1982 to 1987. However, Puttock et al's article is interested in the stumpage prices sawmills paid whereas our paper examines stumpage prices as an input for logging firms' production process. The difference amounts to the value of the timber stand versus the value of the timber delivered to the mill. Leefers and Potter-Witter (2006) recently published an article on stumpage appraisal in the Great Lakes area, but the analysis was only concerned with softwood. Their article looked at stumpage appraisal in the Great Lakes area and includes both state and US Forest Service sales, but only looks at sales where spruce, pine, and fir consist of more than 50% of the volume of the sale. The analysis is based on a total of 427 observations from the period of April 2000 to March 2004.

There were a few articles regarding hardwood forests, but none of them were for northern hardwoods in Michigan. One of the stumpage appraisal articles for hardwoods was for Appalachian hardwoods (Boltz 2002) and another was for hardwood forest in Vermont (Sendak 1991). Even though there were few recent articles that included northern hardwoods in the Great Lakes area, the general transaction evidence appraisal literature did guide our selection of variables to include in our regression. The study by Boltz (2002) used econometric results to show that stand heterogeneity lowers the bid prices for timber sales. The emphasis is that species diversity increases the cost of managing stands and diversity has a negative implicit price on the sale price of the stand. This is expected due to higher production and transaction costs from harvesting, sorting, and milling increased species and products. The study looked at timber sales in Appalachian hardwood forests in the Pisgah and Nantahala national forest from 1979 to 1991.

Another article that assisted in variable selection was Sendak's (1991) US Forest Service report that studied timber sale value as a function of sales characteristics and the number of bidders. The study was done with timber sold by sealed-bid auction in the Green Mountain National forest in Vermont and showed a positive relationship between number of bids and winning-bid value. The author speculates that the number of bids may be a proxy for unmeasured characteristics of the forest stand or an indicator for stand quality. Sendak's results reflect the auction theory prediction that winning-bid values increase with the number of bidders (Engelbrect-Wiggans 1980; McAfee and McMillan 1987).

Finally, Kluender et al. (1998) and Jackson and McQuillan's (1979) articles helped determine some variables regarding the technical problems in harvesting timber and methods of cut used in forestry management. Kluender et al.'s article found that harvest costs were inversely related to harvest intensity and tree size, and due to the difference in method of cuts, some harvesting methods were more profitable than others. The most profitable methods of harvest were single-tree selection in an uneven-aged stand while the least profitable were selection in an even-aged stand, clear cutting and shelterwood harvests. One of the goals of Jackson and McQuillan's study was to provide a valuation model that could be used in forest planning. This study develops a stumpage valuation model for three ranger districts of the Lolo National Forest which is located in western Montana and consisted of 52 timber sales over a 10 year period. This study found that the amount of a forest stand that is designated to be clear-cut increased the amount of bid for the sale. In both studies, some type of method of harvest or cut was a significant variable in the final bid. An interesting point is that clear cutting as a method of cut was significant in the two studies but the effect was in opposite directions.

In summary, the literature review of forest stand valuation and stumpage appraisal methods showed that there are few recent studies on hardwood forests in Michigan. There were a handful of articles regarding the Great Lakes area but these were not specifically about Michigan. Even when a study included Michigan forest sales data such as Leefers and Potter's (2006) paper, the types of forests appraised did not include northern hardwood forests. Moreover, most of the articles that were found were done in the 1980s and 1990s. The hedonic timber appraisal model in this paper fills a gap in the literature by providing an update in the timber appraisal model with recent data and by using a dataset that is much larger than the datasets used in the studies in our literature review. Even though few articles used datasets that shared all the characteristics of our data, they were useful in providing information on variable selection and in building our hedonic timber appraisal model.

3. Econometric Model and Theoretical Framework

The goal of the paper is to estimate a stumpage appraisal model for DNR managed forest stands. We used hedonic pricing theory and regression analysis to estimate a model that will predict what logging firms are going to bid for the right to harvest. Hedonic pricing theory is very useful in problems where it is necessary to value products with heterogeneous characteristics because the theory decomposes the price of a good into the marginal values of a goods attributes or characteristics (Ladd and Martin 1976). The sum of the values of these attributes or characteristics can then be used to estimate the value of the good. Evaluations to discover the implicit prices or marginal values for intermediate products have been done on many different agricultural products including wheat (Veeman 1987; Espinosa and Goodwin 1991), cotton (Ethridge and Davis 1982; Bowman and Ethridge 1992), and tuna (McConnell and Strand 2000). One of the earliest papers written on hedonic pricing theory was about the quality attributes of asparagus (Waugh 1928).

In this paper, hedonic pricing theory helps us estimate a sales bid price by decomposing a forest stand into a bundle of attributes and by assigning marginal values to those attributes using the observed prices in the DNR dataset. The rationale for decomposing goods into bundles of attributes comes from Lancaster's contribution to hedonic theory where he shows that goods are substitutable because of their attributes and characteristics. Before Lancaster, the general consensus was that "goods are goods" and economist ignored the role attributes played in consumer utility. Lancaster assumes that goods are not the direct objects of utility and argues that it is the consumer derives his utility through consumption activities of a good's characteristics (Lancaster 1966). Within a forest stand, it is possible to find different grades and quality of timber as well as many different species of trees. A profit maximizing firm will select the best grade and quality of tree to use in producing their final product. For example, trees of higher quality and popularity wood can be used as veneer and would fetch a higher price in the timber market than trees destined to become paper products. The review of timber transaction evidence and timber stumpage appraisal literature shows that it is possible to decompose forest stands into attributes and use the price of the forest to assign marginal values to the attributes.

In this paper, we use hedonic theory to find a regression for forest stands and the hedonic theory is thus applied to intermediate goods—goods that are used in the production of other goods—and not consumer goods. Instead of maximizing utility, the goal for our analysis is to maximize profits of the firm bidding on the forest stand subject to technology constraints in production. For producers, inputs are useful because they have characteristics that will be used in the production process. Thus, the production value of an input depends on the characteristics and the amounts of characteristics the input provides. The price that a firm then pays for an additional input is the marginal value of output at market equilibrium.

If the hedonic pricing theory is to be applied to a product class and implicit prices are to be estimated, there needs be enough goods with different combination of attributes and characteristics (Freeman 2003). The resulting regression is the joint envelope of the consumption and production function for various packages of goods (Rosen 1974) and the values should not be interpreted as either supply or demand effects. Since the observed price or the coefficient of the regression based upon hedonic regression is a result of market equilibrium this means that the regression coefficient should not be interpreted as what consumers will pay for the good, but rather the interaction of producers' willingness to produce goods with differentiated bundles of attributes and consumers' willingness to pay to consume these goods (Epple 1987). In the regression based on hedonic theory then, marginal values may represent resource costs or user valuation (Triplett 1986). If, however, the consumers demanding the product are identical, then the regression analysis will identify a unique inverse demand function (Milon, Gressel et al. 1984; Freeman 2003).

The relevant hedonic model we will be using with the DNR data is Palmquist's (1989) hedonic model to derive a rent schedule for agricultural land as an input into farm production processes (see also Petrie and Taylor's (2007) article about irrigation rents to agricultural land). Palmquist treats land as a heterogeneous factor of production with characteristics such as soil type, topsoil depth, building structures, all of which can be used as inputs in varying degrees by a farmer in a production process for outputs. The hedonic model for agricultural land provides the theoretical framework to formulate stumpage estimation model.

In the hedonic model for land rental prices as presented by Palmquist, the rental value of the agricultural land is determined by $P=P(z_1, z_2, \ldots, z_n)$ where P is the rent that is paid for the land and z_i are the characteristics of the land that determine P. For the DNR forest stand sales bids data, the high bid amount observed depends on the forest stand's characteristics and can be represented by a hedonic equation such as

$$R = R(q_1, q_2, \ldots, q_n, h_1, h_2, \ldots, h_n) \,, \qquad (1)$$

where R is the amount of the winning bid, and instead of having a vector z_i of characteristics for the agricultural land, q_j and h_j are both vectors of characteristics from the forest sale prospectus where q_j is the species-products in volumes that are in the sale and h_j are the information and harvest requirements the DNR establishes in the sales prospectus. Since the hedonic equation is the result of the interaction between suppliers and demanders, the equation (1) is the equilibrium where demand equals supply.

In order to calculate the implicit prices logging firms are willing to pay for forest stand characteristics, it is necessary to consider the firm's profit maximizing model. Palmquist uses the term "variable profits" and defines it as the difference in value of the outputs and the non-land rental costs. Using this definition, the analogy to variable profits for timber stumpage would be the difference between the value of timber outputs and value of all other inputs to production except the bid amount. Since it is assumed that the firm wants to maximize profits, the profit maximizing model for the logging firm becomes,

$$\text{Max } \pi^{VP} = \sum_{j=1}^{m} p_j q_j - C(x, q, h, \alpha) \qquad \text{with } \pi^{VP} \geq 0\,, \tag{2}$$

where π^{VP} is the variable profit of the firm for producing a vector of species-product volumes, q_j, and selling them per unit at prices represented by the vector p_j. The firm's profit model is subject to its production function which in turn determines the costs of producing the goods. Costs for the firm is dependent on the non-stand related inputs (x), the quantity of a vector of species-products harvested (q), the vector of requirements and other stand information in the sales prospectus (h), and the characteristics of the firm (α). The non-stand related inputs may include transport to deliver the timber from the logging site to saw or pulp mills, wages to pay employees, and maintenance and running of machinery.

The profit maximizing model can be rewritten in terms of output supply and non-bid related input demand where demand is,

$$x = x(q, h, p, \alpha)\,. \tag{3}$$

When substituted into the variable profit function, the profit maximizing model, π^{*VP}, becomes,

$$\pi^{*VP} = \sum_{j=1}^{m} p_j q_j - C(p,q,h,\alpha) = \pi^{VP}(p,q,h,\alpha), \tag{4}$$

and the total profits from a stand would be represented by

$$\pi^{total} = \pi^{*VP} - \theta, \tag{5}$$

the difference between the variable profits and the bid. By rearranging the total profit equation, we find that the bid is the difference of the variable profits and total profits, $\theta = \pi^{*VP} - \pi^{total}$. The bid can now be shown to depend on the characteristics of the stand, the price of outputs and inputs, and characteristics of the firm. Following Palmquist (1989) and consistent with Equation (5), we need to take into account the logging firm's desired profit level, π^D. The bid function is thus defined as,

$$\theta(p,q,h,\alpha) = \pi^{*VP} - \pi^D = \sum_{j=1}^{m} p_j q_j - C(p,q,h,\alpha) - \pi^D. \tag{6}$$

In order to derive the implicit price or the marginal value of the forest stand's characteristics, take the partial derivative of the bid function with respect to a characteristic of the stand,

$$\frac{\partial \theta}{\partial q_j} = \frac{\partial \pi^{VP}}{\partial q_j} = p_j - \frac{\partial C}{\partial q_j}, \tag{7a}$$

$$\frac{\partial \theta}{\partial h_j} = \frac{\partial \pi^{VP}}{\partial h_j} = -\frac{\partial C}{\partial h_j} \quad . \tag{7b}$$

Equation (7a) is the implicit price the firm would increase the bid by for an additional unit of a species-product. This implicit price is equal to the market equilibrium price for the species product less the cost the firm incurs to harvest that additional unit. Equation (7b) is the marginal cost for the firm to harvest a stand following given the stand information and following the requirements that are detailed in the DNR sales prospectus. This is the amount that the firm will decrease their bid given the information and requirements.

The price firms are willing to pay for the right to cut is based on the input values of the forest stand (Ladd and Martin 1976). From our literature review and model, we know that some of the product's characteristics logging firms consider to be important are characteristics of the timber stand such as species, product, volume, etc. The firm's decisions are constrained by the cost of harvesting the forest stand which affects the amount it is willing to bid for the harvest contract. Since the firm's bid should be the sum of the values of the attributes of the forest stand, it is possible to use hedonic price theory to derive implicit prices for the different attributes that can be specified by a linear equation,

$$P = \sum_i \beta_i X_i + \varepsilon \ , \qquad (8)$$

With P_i being the price of the timber sale, the vector of attributes represented by X_i, the coefficients or marginal values of these attributes as β_i, and ε as the stochastic component to the timber sales. The coefficients, β_i, would represent the implicit price for an additional unit of a species production (Equation (7a)) or the implicit cost for the firm to harvest according to the requirements in the sales prospectus (Equation (7b)). Thus, the sum of the implicit prices and costs times their quantities of the different attributes is what a logging firm is willing to bid for the right to harvest the stand.

Though we are estimating the equilibrium values firms are receiving from harvest activity, hedonic analysis does not tell an economist about any of the underlying structure of supply and demand for the good. Rather, the hedonic regression is an observation of equilibrium points of the market of the traded good—where consumers' demand and producers' supply intersect. With that in mind, it is only appropriate to use the hedonic regression to estimate stumpage appraisal when additional units of timber harvested do not significantly affect the market price of the species-product harvested. The regression can provide the equilibrium bid value if the model is predicting the value of a stand if the timber from the harvest does not affect market equilibrium. The regression can provide equilibrium bid value for a whole stand, but not all stands in the state of Michigan if they were to be harvested at the same time. The hedonic regression is also applicable when measuring the marginal change in species-product volume regardless if it is one stand or all stands. This timber appraisal hedonic model was aimed at providing the logging firms' marginal value of Michigan's state owned forest stand characteristics when the number of stands harvested has no affect on the market equilibrium price of timber.

4. Methods

4.1 Dataset

Our data came from sales bids during the period 2004-2008. The data were collected by the DNR as part of their competitive bidding process to select firms to harvest timber. We received an Access database from Douglas Heym (Timber Sales Specialist in the Forest, Mineral, and Fire Management Division at the DNR). Timber sales are organized by stands of trees--a stand is a group of trees that is sufficiently uniform in species composition, age and condition that it can be managed as a group. In the case of the DNR data, we considered each sale prospectus to be for a stand of trees. The hedonic method is then used to identify the contribution of specific volumes of species-product to the overall sale price.

The data for our estimation includes all sales during this period where a contract to harvest has been awarded. Timber sales are advertised by DNR through its website and by emails sent to pre-qualified firms. The advertised sales prospectus includes information about tree species, products, volume estimates of timber for each species-product, forest management unit, open bid date and sale date. The database given to us by DNR also includes a list of firms bidding for specific sales. Interested firms submit bids in a sealed auction format. The DNR also sets a minimum bid price and will pull a sale from auction if the minimum bid price is not met in the bidding process. The firm with the highest bid for the sale is awarded the contract. The winning firm then has 21 days to complete various administrative tasks and obtain insurance before the contract is awarded to the firm. The dataset only contains observations from state managed forests.

The dataset from the DNR contained 2,489 observations. Of these observations, there were four uncompleted sales. Of the completed sales, one sale consisted of trees in unites of acres and was excluded from the model. Since we were interested in only pulpwood or sawlogs, we also excluded 35 sales that contained bolt wood products. In the final analysis, 2,449 sales were used to estimate a hedonic regression for stumpage appraisal.

4.2 Variable Descriptions

4.2.1 Dependent variable: Winning bid adjusted for production price index

The dataset from the DNR contained all of the bids for a sales prospectus that occurred from 2004-2008. Since the DNR conducted a sealed-bid auction and awarded the sale to the firm with the highest bid, the highest bid was used as the dependent variable after it was adjusted for inflation. We used the production price index for lumber from the United States Bureau of Labor Statistics to adjust for inflation instead of the consumer price index using 2004 as the base year. The consumer price index measures the cost of a basket of goods and services to the consumer whereas the production price index measures prices as they enter the first significant commercial transaction (USBLS 2008).

4.2.2 Independent variables

Demand side variable: Housing starts

The DNR dataset did not include housing starts as it is not a variable that would directly affect a firm's bid for a sale. However, housing starts is a variable that affects the demand for sawlogs, and since a hedonic regression represents the intersection between the demand and supply curves (Rosen 1974) the housing starts variable is included in the hedonic regression for stumpage estimation. We obtained the housing starts data from the United States Census Bureau website (USCB 2008).

Sale characteristics: Number of bidders and number of species-products

Sawlogs are measured in thousand board feet (MBF) while pulpwood is measured in cords. We kept sawlogs and pulpwood in the same respective units to estimate the hedonic regression. The number of bidders was the number of firms that bid on the sale prospectus and was calculated from the dataset with the list of firms that submitted a bid for the sale. The number of species-products was the number of unique species and products that were found in the sale and was also calculated from the DNR sale data. For example, if a sale contained both pine pulpwood and pine sawlog, there would be two different species-products because pine pulpwood would be one unique products and pine sawlogs would be another unique product.

Time: Quarter dummy variable

The high bid was adjusted by the producer price index to account for the annual changes in prices. In order to account for quarterly fluctuations, we included quarterly dummy variables. These variables were calculated with the first quarter as being from January to March, the 2^{nd} quarter as being from April to June, the 3^{rd} quarter as being from July to August, and the 3^{rd} quarter from September to December.

Method of Cut

Logging or timber harvesting and timber processing are part of the economic benefits of forestlands and timber harvesting is also a tool for forest managers. Different cuts may be prescribed to a forest stand to improve the quality of the remaining or future trees and to provide a better environment for regeneration. Though there are a number of methods of cuts that are available and can be used by the DNR, only one method of cut is used to harvest all specie-products described in any individual sale prospectus. The nine methods of cuts (MOC) are delayed, final harvest, delayed removal, salvage, seed tree, selection, shelter, shelter prep, or thinning. The descriptions of the MOC in this section were taken from various Michigan DNR sources found on the internet (Pilon and Stephens 2007).

Cuts are often described by the residual basal area left after harvest has been completed. Basal area is the cross-sectional area of a tree 4.5 feet above the ground. Thus, the residual basal area describes the basal area left after a harvest has been completed. A final harvest is the same as a clearcut where the residual basal area is 0-10 ft^2/acre. A variation of the final harvest is the delayed cut or the delayed removal cut. The difference between the three cuts is composition of the understory or forest floor.

In a final harvest the understory is seedling sized and regeneration of a new stand of trees will be difficult to obtain after the harvest. Since it will be difficult for the stand to naturally regenerate, clearcutting is often used when a new species is preferred and additional work will be done by the forest management unit (FMU) to prepare and stock the cleared area (Koelling and Kidd 1985). Clearcutting is also used when the desired species management wants is shade intolerant and the MOC is used since it removes any overstory that may inhibit growth. In a removal cut, the understory is capable of regenerating a new stand of trees. The removal cut is designed to promote growth of trees that are less than 20 years of age. In a delayed removal cut, the trees left after the harvests that continue to mature are greater than 20 years of age.

A seed tree cut produces a residual basal area of 10-30 ft^2/acre. The seed tree cut removes all trees except for a small number of widely dispersed trees that repopulate or re-seed the stand and provide shelter for regeneration. The trees left to repopulate or re-seed are then removed in a later cut. Both the shelterwood and shelterwood prep cuts are related to the seed tree cut as these two cuts also involve cutting most but not all of the trees with the remaining trees creating a microclimate to shelter any new seedlings as they mature.

Selection cut produces a residual basal area of 50-90 ft^2/acre. In a selection cut, individual trees are removed throughout the stand. A selection cut is usually applied to multi-aged stands and are designed to promote the growth of remaining trees to produce a higher quality forest. Selection cut can also produce multi-aged stands versus clear-cutting which will generally produce an even or single age stand. Multi-aged stands are different from even or two-aged stands where the trees are of similar ages such as in a plantation, or in a two-aged stand where seed trees may have been used to repopulated a stand to produce a two-aged system. Another reason to use selection cut is to remove trees that are of lesser quality to provide space for better quality trees to mature and restock the forest stand. Even though a selection cut can be used to harvest valuable sawlogs, both pulpwood and sawlog products are produced in the cut.

Thinning—another MOC— is usually applied to even or two-aged systems. The residual basal area can vary from 110 ft^2/acre to more than two-thirds of the original basal area. Salvage cuts are usually applied to stands that have been damaged by forces such as fires, pests, or winds.

There were a couple of options in grouping the method of cut. We considered using the method of cut descriptions as provide by the DNR to create five different cut categories by grouping together final harvest, delayed removal, and removal; seed tree, shelterwood, and shelterwood prep; and to have separate groups for selection cut, thinning, and salvage. We also considered ways of grouping method of cuts according to how the cut would affect bidding values, as well as grouping method of cuts with few observations in the dataset.

After speaking with Dr. Michael Walters, a forestry expert in our forest ecology and economics team, we found that residual basal area and the equipment necessary for the cut are factors affecting the difficulty and cost of a type of harvesting method. If the residual basal area is rather large and few trees are harvested, it may be difficult and more time consuming for the logger to get into the forest stand to harvest but the equipment needed for a cut with a high residual area may be less. A possible advantage to a selection cut with a high residual basal area is that the trees harvested are of better quality and are likely to be high valued sawlogs. On the other hand, leaving a small basal area and harvesting a large volume of trees may require more equipment which can possibly increase capital cost for the logging firm. The larger volume of timber harvested will also mean increased revenue when the firm sells the timber to mills. Dr. Walter's information regarding harvesting costs in Michigan matched Kluender et al. (1998) who found that harvesting costs of shortleaf (*Pinus echinata* Mill.) and loblolly pine (*Pinus taeda* L.) in southern states depended on how much basal area was removed and the size of the trees in the forest stand. The most profitable cuts for the logging firms were single-tree selection in an uneven stand while less profitable were selection in an even-aged stand, clear cutting , and shelterwood cuts.

For the DNR dataset, the top three most popular cuts prescribed were final harvest, selection cut, and thinning and these MOCs were kept as they were and not regrouped. These three types of cuts accounted for about 89% of all the sales. Seed tree and shelter cuts accounted for almost 7% of all sales and delayed removal, removal, salvage cut, and shelter prep together accounted for almost 4% of all sales. We kept seed tree and shelter cuts as two different MOCs. With harvest cost and the DNR MOC distribution in mind, we decided to find a way to group delayed removal, removal, salvage cut, and shelter prep cuts because they only accounted for 4% of the sales. Since delayed removal and shelterwood prep both leave trees that are older –a delayed removal releases trees in the understory that are greater than 20 years and a shelterwood prep is designed to prepare the stand for another cut in 10 years—these two cuts may present the same difficulties to loggers and so we grouped delayed removal and shelterwood prep together. The descriptions of removal and salvage shows that these cuts leave an understory that is relatively young and sufficient to regenerate and develop a new age class and so removal and salvage were also grouped together. Statistical analysis also showed each group had similar mean high bid values.

In our discussion with Dr. Walters regarding the method of cut, he also pointed out that there were confounding factors to the different method of cuts. As data analysis showed, sawlogs tended to be harvested using selection harvests whereas pulpwood was harvested using thinning or final harvest. However, since these four method of cuts were such a small proportion of the data set, we were not concerned that they would have a big impact on our regression.

Location: Forest Management Units

The dataset included information about which FMU the forest stand was located. There are a total of 15 forest management units in Michigan. The eight FMUs located in the Lower Peninsula (LP) are Atlanta, Cadillac, Gaylord, Gladwin, Grayling, Pigeon River, Roscommon and Traverse City. The seven FMUs located in the Upper Peninsula (UP) are Baraga, Crystal Falls, Escanaba, Gwinn, Newberry, Saul Ste Marie, and Shingleton. A map of the FMUs can be found in Figure 2.

We are not as concerned about the exact locations of forest management units and decided to group FMUs into those in the Upper and Lower Peninsula. In a future models concerning our study area in the UP, the individual FMU locations may be of more importance and may be reinstated into the model.

Specie-Product variables

There were originally 65 variables for the set of species-products that were found in the DNR dataset. A forest stand by definition is a group of trees that are of similar age and composition that can be managed together. Since the DNR forestlands contain many species, forest stands will not contain all of the species and the composition will vary from stand to stand

and area to area. When a sale is advertised, the DNR lists the volumes of species-products they estimate a firm will harvest and the species-products the FMU wants the firm to harvest from the forest stand. When a specie-product is not found in a stand, it will have an observation value of zero volume.

From the 65 original variables in the DNR dataset, we reduced the number of specie-product variables to 47. Of the 65 species-product combinations in the data, there are 22 species-products variables with less than 30 non-zero observations. Moreover, the data also shows that non-zero observations for the species-products are not a large percentage in the sales in which they occur (consisting of only 4% of the total volume). Since there are not enough non-zero observations for these variable coefficients to be estimated with precision in the regression, we decided to consolidate these 22 species-products variables and reduce the number of variables in our regression.

Of the 22 species-products variables, five of these variables were broad groupings of tree species. The five broad groups were miscellaneous species pulp, other species pulp, mixed pine sawlog, mixed softwood sawlog, and other species sawlogs. Of the 65 original variables in the DNR dataset, there are a total of 13 broad grouping of tree species variables. Additional broad groupings of tree species were mixed oak and mixed aspen. We mention these broad groupings because we considered using them to reduce the number of variables in our regression.

One of the options to deal with low observation species would be to ignore the species with low volumes in the sale. This option was not pursued because preliminary regressions showed that dropping these variables would change the significance of the coefficients for the remaining regression variables. A second option would be to pool these species with similar species or species groups. A third option was to create a "general" category to pool such observations.

The second option of consolidating variables was to group together low non-zero observation variables that were in the same genus or family. However, this option was not used because data combining all the variables in the same genus or family would not increase the number of non-zero observations enough. Since specific and broad group species categories occur together in individual bid reports, these co-occurrences were evidence to us that foresters marking and doing inventory on the stands are making distinctions between species and did not support the option of consolidating specific species with the broad groupings. For example cottonwood is a deciduous tree and could be consolidated with the mixed hardwood group. However, the dataset shows that sales containing mixed hardwood pulp also contain cottonwood pulp. Since cottonwood occurs with mixed hardwood, we could not dismiss the possibility that foresters who did reconnaissance for the sales prospectus consider cottonwood to be different from mixed hardwood. Therefore, variables were not consolidated based on genus or family since these groupings were not reflected in the data.

In the end we decided to consolidate all the 22 species-product variables with < 30 non-zero observations into two general species variables—one for pulpwood and another for sawlog products. After the species-products consolidation, the final variable count for species prouducts included 28 specie-product variables describing pulpwood and 19 describing sawlog.

As part of the specie-product variable analysis a correlation matrix was calculated, and it revealed that basswood pulpwood and sawlog, and mixed oak pulpwood and sawlog had a correlation coefficient ≥ 0.8. A high correlation coefficient between independent variables causes uncertainty in the regression coefficient and overstates significance in the estimation results. However, it was not possible to combine sawlog and pulpwood of these species because we were using different units for the two products and wanted to remain consistent for all the species.

A final variable related to the specie-product variable set are the number of species-product in a sale prospectus. In order to calculate the number of species-product we counted each combination of specie and product. For example, if a sale contained mixed pine pulp, mixed pine sawlog, and white pine pulp, there would be three species-products in the sale.

4.2 Summary Statistics

In order to understand our dataset better, we ran a series of summary statistics on the variables. We ran statistics to find out what MOCs were used, where in Michigan the sales occurred, the average volume of pulpwood and sawlog in the sale, and the average number of bidders as well as the number of species-products for a sale. These statistics showed that the three most popular cuts were final harvest followed by selection harvest and thinning. When sawlogs were present in the cut (n=2,057), the percentage of sales that used a selection cut was slightly higher than the overall dataset (26% compared to 22%). When the sale consisted of only pulpwood (n=392), final harvest was by far the most common MOC consisting of 75% of the MOC used, and the second most common MOC was thinning (13%).

As for the location of the sales, 59% were found in the LP and 41% in the UP. When broken down by FMU, Traverse City had the most sales with Pigeon River having the least—both of these FMUs are located in the LP. In the UP, Grayling had the most sales while Baraga had the least. Sales in the LP had on average 942 cords of pulpwood and 147 MBF of sawlog while sales in the UP had 1200 cords of pulpwood and 46 MBF of sawlog. The average volume of a sale for the dataset was 1,046 cords of pulpwood and 106 MBF of sawlogs. On average there were four bidders per sale contract and an average of 6.6 species-products per sale. The average winning bid was $63,564 after adjusting for inflation. These summary statistics can be found in Table 2.

5. Regression Model

A hedonic regression function was estimated for DNR forest stands that were sold between the period 2004 to 2008. The final regression consisted of 61 variables and had an adjusted-R^2 of 0.94. A joint F-test for all the variables did not support the hypothesis that all variables were equal to zero.

In our regression, the dependent variable is the value of the winning bid as adjusted for inflation in the sale. The independent variables include the number of bidders, the number of species-products in the original data as well as the quadratic of species-products, and species-product volume in cords for pulpwood and MBF for sawlogs. There are also dummy independent variables including the quarter the sale was advertised, the method of cut for the sale, and the FMU that issued the sale. A list of the variables and descriptions can be found in Table 1.

From the review of transaction evidence appraisal literature and from our discussions with Dr. Walters, we expected sugar maple sawlog to be a high value product with a significant positive coefficient that would increase the value of the final bid. We also expected the number of species-product in a sale to have a negative coefficient and the number of bidders to have a positive coefficient. We reasoned that as the volume of timber increased loggers would have more cords to sell and therefore a higher return on a single harvest. However, the number of species-products would decrease the stumpage value because the products would need to be separated and transported to different sawmills for processing.

The only non-linear variable was the number of species-products which was included in the stumpage estimation regression as a quadratic variable as well as linear. When considering non-linearity in the variables, our hypothesis was that as the variable increased (decreased) there would be a non-linear increase (decrease) in the final bid value.

6. Estimation Results

In this section we will examine our regression results and interpret some of the coefficients. For our hedonic regression model we considered non-linearity for the number of bidders and the number of species-products in a sale. When we introduced a squared-bidders variable ($bidders^2$) into the regression, the regression coefficient for this variable was insignificant and no further effort was made to examine this regression equation. When the quadratic species-products variable ($species\text{-}products^2$) was included in the linear equation the new variable was significant. Furthermore, the adjusted-R^2 with the $species\text{-}product^2$ variable was slightly larger than that of the regression that was linear in variables. Since the addition of the $species\text{-}products^2$ variable provided an interesting economic interpretation and increased the adjusted-R^2 value, the final hedonic stumpage appraisal regression was non-linear in variables.

The sign for the coefficients for the species-product and number of bidders were what we expected. The number of bidders had a significant positive coefficient with each additional bidder increasing the final bid amount by $1,439. The coefficient for species-product was negative (-$2,283.49) but the $species\text{-}product^2$ was positive ($130.42), and this was interpreted to mean that sale bids would decrease with an increase in species-products but at some point, an additional species-product in the sale would result in an increase in the bid amount. Holding all other variables constant, at the average number of species-product found in the dataset an additional species-product decreased the bid by $327.19 and with one less species-product the bid increased by $588.03. It is possible that as logging firms are faced with more species-products in the forest stand, the firm may send several species-products to the same mills together and reduce or prevent further processing costs for the firm. The coefficient for the housing starts variable was also positive and significant. A thousand unit increase in housing starts would increase the bid value by $46.81. The results of these variables are summarized in Table 3.

Not all species-products would be in a sale, and since we did not include a total volume variable, there was no need to drop a specie-product variable to accommodate strict collinearity. Of the 28 pulpwood variables, 19 of these variables were significant with 15 variables significant at the 1% level and 4 variables significant at the 5% level. Of the 19 sawlog variables, twelve variables were significant with eleven variables significant at the 1% level and one variables significant at the 5% level.

Reviewing the regression coefficient results, we wondered if some of the products from the same genus or family could be grouped together and if these variables had coefficients that were different from each other. We performed an F-test on aspen variables and oak variables to test this hypothesis. From conversations with Dr. Walters, we found that there was not a big difference between quaking and big tooth aspen except that big tooth aspen would grow to be bigger trees. Our hypothesis was that quaking and big tooth aspen pulpwood could be grouped together whereas quaking and big tooth aspen sawlog would not be due to the differences in size of the trees that would produce sawlogs. We wanted to know whether the regression coefficient for quaking, big tooth, and mixed aspen pulpwood and sawlog were different from each other.

The F-statistics supported the hypothesis that big tooth and quaking aspen pulpwood had the same regression coefficients and could be grouped together. F-statistics also supported the hypothesis that the regression coefficients of mixed and big tooth aspen sawlogs were the same. This indicated that when submitting bids for aspen products, loggers may view big tooth and quaking aspen pulpwood as similar products. However, loggers priced big tooth aspen sawlogs differently from quaking aspen sawlogs. Big tooth aspen are bigger trees than quaking aspen and it is possible that mills may pay more for sawlogs that can be made into products with larger dimensions. If this is so, then the price logging firms receive from big tooth aspen sawlogs may be greater than the price they receive for quaking aspen sawlogs and if both species-products cost the same to cut, then it may account for the higher implicit prices firms are willing to pay to harvest big tooth aspen .

From our summary statistics, we knew that basswood and mixed oak products had a high correlation coefficient. We had several oak variables (white, red, and mixed oak), and our hypothesis was that the quality characteristics of the wood would prevent them from being grouped again. An analysis of the regression coefficient results showed that the regression coefficients for red oak pulpwood and white oak sawlog were not significant. Nevertheless, we tested whether the regression coefficients for red, white, and mixed oak pulpwood and sawlog were different. The null hypothesis was that oak species' regression coefficients would be the same but after conducting our F-tests, this hypothesis could not be supported at the 5% level of significance.

We also tested whether regression coefficients for the different products of the same species were equal. Not surprisingly, when one of the products in the pair did not have statistically significant regression coefficient results the F-statistics supported the null hypothesis that the pulpwood and sawlog regression coefficient of that product were equal. These species included basswood, beech, paper birch, quaking aspen, and white oak.

According to our regression, the most valuable sawlog was yellow birch while the second most valuable sawlog was sugar maple. This result was surprising because our conversations with Dr. Walters indicated that sugar maple was a very fashionable sawlog and would therefore have a high demand in the market and be a desirable species to harvest. However, after reviewing the frequency at which yellow birch and sugar maple sawlogs occurred with other species, we found that yellow birch sawlogs also occurred with other highly desirable species such as black cherry and oak while sugar maple was more plentiful and occurred with many types of species of varying value. Yellow birch is found with other desirable species and this may explain why its regression coefficient was greater than the regression coefficient for sugar maple. If timber quality is more variable from sales with sugar maple sawlogs, there may be higher processing costs than when quality might be more uniform in stands with yellow birch. Higher costs for harvesting sugar maple sawlogs may account for difference in marginal values of yellow birch and sugar maple sawlogs.

The regression coefficient results indicated that all MOCs were different from the MOC group removal and salvage. We conducted F-tests to find out if MOCs were priced significantly different from each other. A joint F-test did not support the null hypothesis that the regression coefficients of all the MOCs used in the regression were equal. F-tests for pairs of MOCs confirmed the hypothesis for the joint F-test and provided information on which MOC variables were different. F-tests for shelter cut with other MOC were significant at the 10% level while F-tests for the removal & salvage group with other MOC were significant at the 5% level.

7. Discussion and Conclusion

Since forest stands are heterogeneous goods and it is difficult to find two forest stands that are identical, the implicit prices from the estimated regression can then be used to estimate the values of forest stands with different characteristics. By applying the hedonic pricing theory to forest stand sales data, we found the implicit prices of different species-product, method of cuts, and forest stand location. Since the data used included softwoods and hardwoods, this paper adds to the timber valuation literature by looking at more heterogeneous stands and by considering the impact of this diversity on forest stand valuation.

By using recently collected Michigan DNR data, the paper also fills a gap in the forestry literature regarding current timber stand valuation and the valuation of hardwood stands in Michigan. Though our literature review found articles about forest stumpage appraisal in the Great Lakes area, there were few in Michigan, and those that did contain Michigan DNR data were about softwood stumpage. Though the focus of this regression was not to examine the spatial effect of timber harvests on final bid prices, the regression analysis did analyze the difference that occurred when a sale was found in the Lower versus Upper Peninsula. We found that sales located in the Lower Peninsula were significantly lower in value than those located in the Upper Peninsula. This may be because of the location of mills and facilities to accommodate the forestry industry. Since spatial data is increasingly being used in economic analysis, more work should be done in this area to find out what spatial factors are attributing to forest stand bid prices. If biofuel production with woody biomass becomes possible in the future, the location of such biofuel plants may be an important variable in the bid price of forest stands.

The original impetus for this hedonic timber analysis was to provide a model that could be used with a forest vegetation simulation program that is being developed for the forest ecology and economics project. By using the data generated from the forest vegetation simulation program, the completed models will estimate the value of timber that are managed in the study area and provide a tool for the management of forest stands. For example, Boltz et al. (2002) results indicated that an increase in species-product diversity would decrease the final bid. However, our regression analysis showed that increasing the number of species-products in the stand had a modest impact (compared to mean value) and had a declining effect and may not be as costly as previous literature demonstrated. If forest managers would like to increase species diversity in the future, they may want to reconsider the financial returns to such a management plan. We also found that yellow birch, sugar maple, black cherry, and black ash sawlogs were the sawlogs that had the highest implicit prices amongst the sawlog species found in the dataset. If forest managers would like to increase the value of forest stands, they may want to plant more of these species but this might involve tradeoffs in habitat for birds and animals.

The purpose of this paper was to estimate a stumpage appraisal for northern forest stands in Michigan. To fulfill this objective, we used a dataset of forest stand sales provided by the Michigan DNR and hedonic pricing theory for intermediate inputs to derive the implicit values of the stand characte1ristics. In doing so, the paper fills a gap in the literature by providing an update on stumpage appraisal for the state and a model that can be used for the heterogeneous forest stands of northern hardwood forests as well as northern conifer forests. As part of a larger multidisciplinary ecology and economics project, the model presented in this paper will be used in the future with a forest vegetation simulation model to better understand the tradeoffs of different forest stand compositions and ecosystem management scenarios in the region.

Tables and Figures

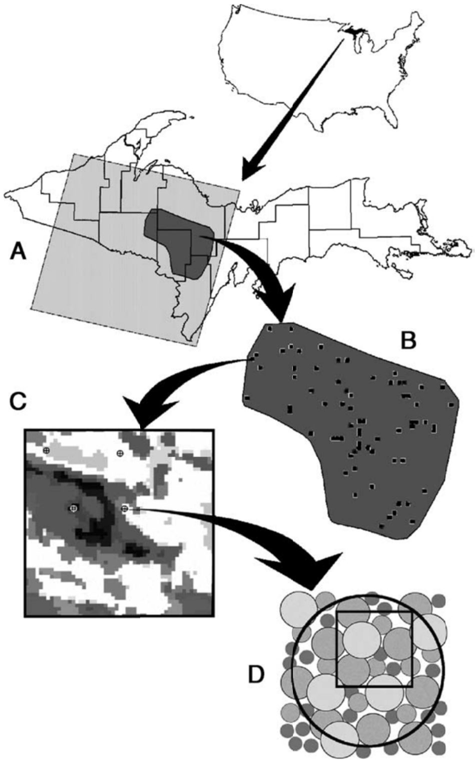

Figure 1. Study area of the Forest Ecology and Economics Project

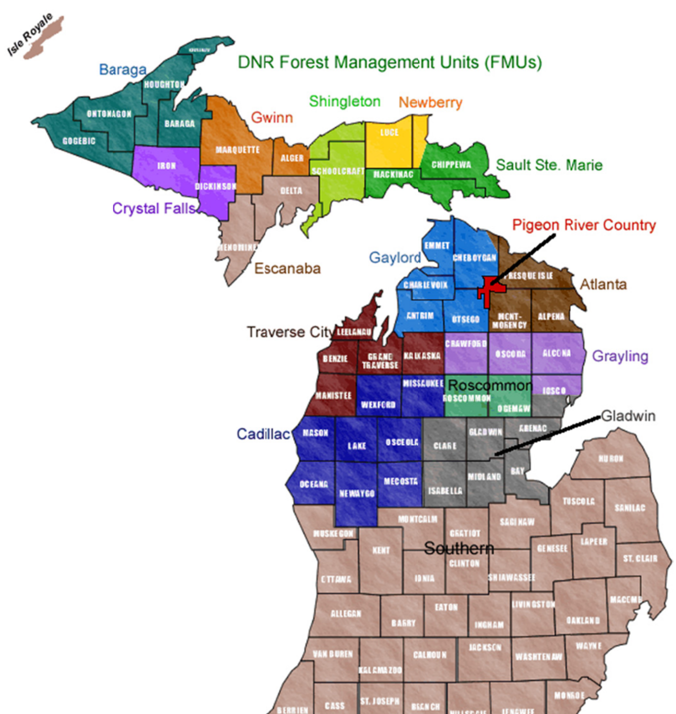

Figure 2. Michigan Department of Natural Resources Forest Management Units

Table 1. Data description

Variable		Measurement
high bid	dollars	winning bid of DNR harvest contract adjusted by PPI
bidders	integer	number of firms bidding for the forest stand sale
species-product	integer	number of species-product involved in the sale
species-product^2	integer	quadratic of species-product
housing	thousand	Number of housing (thousand) starts during that quarter
qtr1	1 or 0	dummy =1 (for sales from January to March)
qtr2	1 or 0	dummy =1 (for sales from April to June)
qtr3	1 or 0	dummy =1 (for sales from July to September)
qtr4 (dropped)	1 or 0	dummy =1 (for sales from October to December)
sawlog variables	MBF	thousand board feet
(see Table 3 for a full list of sawlog species)		
pulpwood variables	cords	
(see Table 3 for a full list of pulpwood species)		
del_sheltprep	1 or 0	dummy =1 (for delayed cut or shelterwood prep)
rem_salv	1 or 0	dummy =1 (for removal cut or salvage cut)
final harvest	1 or 0	dummy =1 (for final harvest cut)
seed tree	1 or 0	dummy =1 (for seed tree cut)
selection	1 or 0	dummy =1 (for selection cut)
shelter	1 or 0	dummy =1 (for shelterwood cut)
thinning	1 or 0	dummy =1 (for thinning cut)
Lower Peninsula FMU	1 or 0	dummy =1 (for sale located in LP)

Table 2. Summary Statistics

Dataset Variables	Mean	SE	Min	Max
Dependent Variable				
high bid	$58,786.58	$67,469.22	$614.59	$1,075,624.00
High bid (adjusted)	$63,563.94	$72,881.56	$714.64	$1,250,726.00
Demand side characteristics				
Housing starts (thousands)	339.99	103.53	162.00	485.00
Timber sale characteristics				
Number of bidders	4.09	2.61	1.00	15.00
Number of species products	6.62	3.11	1.00	21.00
Time				
Qtr 1	0.22	0.42	0	1
Qtr 2	0.33	0.47	0	1
Qtr 3	0.22	0.41	0	1
Qtr 4	0.24	0.42	0	1
Method of cut				
delayed & shelter prep	0.02	0.15	0	1
removal & salvage	0.02	0.12	0	1
final harvest	0.49	0.50	0	1
seed tree	0.02	0.13	0	1
selection	0.22	0.42	0	1
shelter	0.05	0.22	0	1
thinning	0.18	0.38	0	1
Location				
Lower Peninsula FMU	0.59	0.49	0	1
Atlanta FMU	0.07	0.25	0	1
Baraga FMU	0.03	0.17	0	1
Cadillac FMU	0.09	0.29	0	1
Crystal Falls FMU	0.08	0.26	0	1
Escanaba FMU	0.03	0.18	0	1
Gaylord FMU	0.07	0.25	0	1
Gladwin FMU	0.04	0.19	0	1
Grayling FMU	0.10	0.30	0	1
Gwinn FMU	0.08	0.28	0	1
Newberry FMU	0.07	0.25	0	1
Pigeon River FMU	0.02	0.15	0	1
Roscommon FMU	0.05	0.22	0	1
Saul Ste Marie FMU	0.06	0.24	0	1
Shingleton FMU	0.05	0.22	0	1
Traverse City FMU	0.15	0.36	0	1

Table 3. Results of the Hedonic Regression

Adjusted R^2 = .9358

Independent variable	Coefficient	t-values	Independent variable	Coefficient	t-values
Demand side characteristics			Pulpwoods		
housing starts	46.81**	11.04	Balsam fir	14.89	1.49
Timber sale characteristics			Basswood	28.30**	3.51
bidders	1439.18**	8.97	Beech	-3.95	-0.16
species-product	-2283.49**	-4.93	Balsam poplar	-13.13	-0.72
species-product2	130.42**	4.34	Black spruce	35.60**	8.82
Time			Big tooth aspen	46.11**	18.54
qtr1	3051.08**	2.69	Cherry	-6.82	-0.21
qtr2	-3740.16**	-3.38	Jack Pine	46.96**	56.62
qtr3	-4172.63**	-3.59	Mixed aspen	34.97**	19.09
qtr4	dropped		Mixed hardwood	32.99**	22.19
Method of cut			Mixed oak	17.36**	5.58
delayed & shelter prep	10247.80**	2.56	Mixed pine	80.89*	2.17
removal & salvage	dropped		Mixed softwood	28.59**	6.29
final harvest	12683.52**	4.04	NW cedar	24.27*	2.39
seed tree	9021.86*	2.13	Paper birch	17.10**	3.04
selection	11010.82**	3.37	Quaking aspen	45.55**	29.11
shelter	16699.63**	4.73	Red maple	52.42**	11.76
thinning	11553.42**	3.55	Red oak	7.02	1.26
Location			Red pine	66.85**	50.56
Lower Peninsula FMU	-9525.59**	-9.18	Sugar maple	-16.80**	-2.68
Constant	-19395.98**	-5.23	Tamarack	28.14*	2.28
			White ash	171.36**	4.16
			White oak	43.17**	3.93
			White pine	5.47	1.03
			White spruce	24.02*	2.38
			General species	26.72	1.83
			Sawlogs		
			Black ash	579.07	0.37
			Basswood	6.17	0.22
			Beech	7.45	0.09
			Big tooth aspen	107.80**	7.66
			Cherry	630.35**	4.18
			Jack pine	-7.62	-0.43
			Mixed aspen	106.59**	6.61
			Mixed hardwood	141.50**	2.55
			Mixed oak	151.41**	9.31
			Paper birch	-136.14	-1.10
			Quaking aspen	18.27	0.57
			Red maple	-32.69	-1.15
			Red oak	338.07**	19.56
			Red pine	213.38**	97.15
			Sugar maple	1067.79**	51.87
			White ash	-153.02**	-2.53
			White oak	30.40	0.54
			White pine	98.26*	2.02
			White spruce	-421.62**	-3.73
			Yellow birch	1536.13**	6.92
			General species	21.32	0.15

*significant at 5% ** significant at 1%

Table 4. P-values for Paired F-tests for MOC

	Removal & salvage	Delayed & Shelter prep	Final harvest	Seed tree	Selection	Shelter
Delayed & shelter prep	0.012					
Final harvest	0.000	0.409				
Seed tree	0.042	0.720	0.231			
Selection	0.002	0.967	0.096	0.627		
Shelter	0.000	0.064	0.054	0.036	0.005	
Thinning	0.000	0.594	0.568	0.358	0.357	0.036

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