C I N T R A F O R

Working Paper

103

An Analysis of Sale Characteristics on the Timber Sale Value 1989-2005

J. Kent Barr

John Perez-Garcia

September 2006

CINTRAFOR

CINTRAFOR Working Paper 103

An Analysis of Sale Characteristics on the Timber Sale Value 1989-2005

J. Kent Barr
John Perez-Garcia

CINTRAFOR
College of Forest Resources
University of Washington
Box 352100
Seattle, WA 98195-2100

This material is based upon research supported by the USDA Cooperative State Research, Education and Extension Service, the State of Washington Department of Community, Trade and Economic Development, and the State of Washington Department of Natural Resources through a data sharing agreement. We wish to thank Angus Brodie and Brian Lu, WADNR for their assistence. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the funding agencies.

Technical Editor: Clara Burnett

EXECUTIVE SUMMARY

The Washington State Department of Natural Resources (DNR) manages 2.1 million acres of timberland. Timber harvested from these lands has averaged 12 percent of Washington's total annual timber harvest level from 1989 through 2003. Management plans have incorporated more ecosystems goals such as promoting ecosystem health, habitat conservation, and increasing the structural complexity of the timberland. The management plan adhered to by the DNR will likely result in more heterogeneous stands of timber and thus timber sales of more heterogeneous saw timber.

The goal of the study was to examine how the diversity of saw timber in a given timber sale impacted the final sale value in lump sum sales of western Washington. Saw timber diversity was defined by the distribution of volume among different species and saw log grades in a given sale. Prior research predominately located in the U.S. South had shown a reduction in timber sale value as sales included a greater level of saw timber diversity. This result is based on the theory that increasing transaction costs associated with the processing of more heterogeneous stands led to a less desirable timber sale characteristic per sale. These processing costs include harvesting, sorting and the reselling of undesirable timber.

The study focused on lump sum state timber sales in western Washington. Lump sum sales require prospective buyers to bid on the right to harvest an entire timber sale. A parcel is first advertised and then auctioned as one unit, establishing a fixed payment for the timber sale by the winning bidder. Since this method of sale requires the buyer to purchase and harvest all timber advertised in a sale, it can result in forcing buyers to purchase timber species and saw log grades that they have little or no interest in. This rationale led to the hypothesis that a negative relationship would be observed between increasing saw timber diversity and the final sale value of lump sum timber sales in the data. The detailed inventory information provided by the DNR enabled the calculation of an index value for saw timber diversity that could be used as a metric in empirical examination of the relationship between diversity and the final sale value.

A diversity variable was created to facilitate examination of the impact increased heterogeneity of saw timber in a tract has on the final sale value of lump sum timber sales. This required the calculation of a diversity variable that would account for the species and grade characteristics of each individual timber sale. To this end the Shannon-Wiener index was selected as the best method for calculating this variable. It was an appropriate choice for this data because it could be calculated using the detailed inventory information. In this research stand diversity or heterogeneity applied only to the species of trees and log grades that were included in the timber sale data. Wildlife and other facets of a timber stand were not included in the calculation of the diversity index.

The diversity index created had a range of 0 for a completely homogeneous timber sale to 3.689 for a completely heterogeneous timber sale. Slightly less than 800 sales had values from 1.4 and 1.7. Another 700 sales included values from 0.7 and 1.3. About 500 sales had values from 1.8 to 2.2. The remaining sales were distributed above and below these ranges. A total of 2194 sales were included in the study.

Other variables examined in the model to explain the final sold value of the timber sale included the total number of bidders on a timber sale, the total acreage of the timber sale, the contract length of the timber sale, the total number of miles of required road reconstruction, the Douglas fir volume of the saw log grades P, 2P, 3P, SM, 1S, the Douglas fir volume of the saw log grade 2S, the Douglas fir volume of the saw log grade 3S, the Western Hemlock volume of the saw log grades P, 2P, 3P, SM, 1S, the Western Hemlock volume of the saw log grade 2S, the Western Hemlock volume of the saw log grade 3S, all other volume included in the timber sale, and the WWPA lumber index price of Douglas fir. During the process of model fitting a diversity measure of the timber sale accounting for only the distribution among eight possible tree species and a diversity measure of the timber sale accounting for only the distribution among the five possible saw log grades were used in alternative model comparisons.

The final sold value of a timber sale in U.S. dollars represented the winning bid of a timber sale. By including the volume found in the three highest grades of both dominant and co-dominant species, as well as the other sale volume on the right hand side of the equation, the problem of scale with respect to the dependant variable was alleviated. In other words, the existence of large bid values skewing estimates simply due to large volumes was eliminated.

Seven models were estimated with alternative sets of independent variables. There was consistent evidence that the final value of DNR timber sales located in western Washington were negatively influenced by increases in the level of saw timber heterogeneity over the period of study. Heterogeneity among tree species was found to impact final sale value more than heterogeneity among saw log grades. A possible reason for this result is that commodity producers generally focus on a tree species or a certain range of grade classes. For instance a sawmill may be best geared to mill #2 and #3 saw logs, or perhaps a commodity producer uses only Douglas fir in the manufacture of its products. Increasing heterogeneity of saw timber in a lump sum framework forces these bidders to bid on greater volumes that they are not interested in and may in fact have to resell. This is believed to be viewed negatively by bidders as an additional cost of doing business. Alternative theories are likely to exist as well that can increase the cost of harvesting and marketing logs.

The impacts of saw timber heterogeneity are not well serviced by the lump sum method of timber sale. Timber sales in which greater levels of saw timber diversity are observed may return greater revenues to the DNR if another method of sale is instituted. Additional empirical work on heterogeneous timber sales focusing on how the DNR can create bundles of timber from these sales attractive to different bidders would be pertinent.

In addition to the effect of saw timber diversity, this study found significant evidence that an increased pool of bidders and therefore increased competition for a timber sale had a positive impact on the market value. However, the data indicates that the level of competitiveness declined over the period of study. The existence of a competitive framework among bidding firms is a key to achieving a final timber sale value at or near its true market value. Declines in the average number of bidders on timber sales in the data set may be caused by a number of factors. Regardless, these declines may be cause for concern and further research into why they are occurring and what can be done to alleviate the impacts would be relevant.

The total acreage of timber sales in the study region displayed diseconomies of scale. While this result was not predicted, it is not uncommon in the literature. Munn and Rucker (1995) and Boltz et al. (2002) both found significant evidence that parcel size negatively impacts final sale value. However, this variable presents a clear focus for future study to explore why increasing parcel size results in reduced final sale value in western Washington. In understanding the implications of this variable it is important to consider who purchases DNR timber and industry shifts over the period of study.

Research regarding how the DNR could increase the number of bids offered on its timber sales and alter its methods of sale would also be valuable. While increasing the competition among bidders is a good way of increasing the timber revenues annually generated by the DNR's timber sale program, mill consolidation in the state of Washington suggests that there may not be a lot of room for this to occur. Additionally, the DNR would not want to adversely impact business relationships it has developed with large commodity producers. They represent a steady demand for the states timber as well as important sources of employment. Future economic research is needed to determine the feasibility and impact of attempts to improve competitiveness and marketing of DNR timber sales.

TABLE OF CONTENTS

LIST OF FIGURES

PAGE

LIST OF TABLES

PAGE

INTRODUCTION

The Washington State Department of Natural Resources is an important provider of timber in the state of Washington. The Department of Natural Resources (DNR) manages the 2.1 million acres of timberland owned by the state of Washington. Timber harvested from these lands has averaged 12 percent of Washington's total annual timber harvest from 1989 through 2003. The DNR manages timberlands as ecosystems with numerous goals such as producing revenue from timber harvests, ecosystem health, habitat conservation, and increasing the structural complexity of the timberland (WADNR 1997). The management plan adhered to by the DNR will likely result in more heterogeneous stands of timber and thus timber sales of more heterogeneous sawtimber.

The goal of this study was to examine how the diversity of sawtimber in a given timber sale impacted the final sale value in lump sum sales of western Washington. Western Washington was defined as all lands located west of the crest of the Cascade mountain range. Sawtimber diversity was defined by the distribution of volume among different species and sawlog grades in a given sale. Prior research, predominately located in the U.S. South, had shown and implied that increasing stand level heterogeneity of sawtimber negatively influenced timber sales value (Boltz et al. 2002, Leffler and Rucker 1991). These studies base this result on the theory of increasing transaction costs associated with the processing of more heterogeneous stands. These processing costs include harvesting, sorting and the reselling of undesirable timber. As a public agency, the DNR discloses information on all of the timber sales it conducts. This enabled an empirical analysis of the research question regarding the impacts of sawtimber diversity on the final timber sale value of DNR timber sales in western Washington.

This study focused on lump sum state timber sales in western Washington approved by the Board of Natural Resources. Lump sum sales require prospective buyers to bid on the right to harvest an entire timber sale. A parcel is first appraised, advertised and then auctioned as one unit, establishing a fixed payment for the timber sale by the winning bidder. Since this method of sale requires the buyer to purchase and harvest all timber advertised in a sale, it can result in forcing buyers to purchase timber species and sawlog grades that they have little or no interest in. This rationale led to the hypothesis that a negative relationship would be observed between increasing sawtimber diversity and the final sale value of lump sum timber sales in the data. The detailed inventory information provided by the DNR enabled the calculation of an index value for sawtimber diversity that could be used as a metric in empirical examination of the relationship between diversity and the final sale value.

The empirical work of this study used a multiple regression equation in which a timber sales final sale value or market value was used as the dependent variable. The equation was based on the theoretical assumption that the market value of a timber sale is a function of its physical characteristics as well as various market factors. Characteristics include volumes of timber, area, and costs associated with harvest. Market factors can include fluctuations in lumber prices, the export and import levels of forest products, and the robustness of end-use markets for forest products such as the construction of privately-owned homes. The diversity index previously mentioned was included in the vector of sale characteristics that comprised the independent variables of the regression equation.

The following chapter develops background information that provides the reader with a description of the Washington Department of Natural Resources, a brief history of the Pacific Northwest region of which western Washington is a part, and a review of prior literature regarding timber sales. Chapter II outlines the study's model and the data used in its estimation. Chapter III details the empirical model estimation and results. Chapter IV concludes the paper with a discussion of findings and suggestions for future research.

BACKGROUND

Timber lands owned by the state of Washington are managed by the WA Department of Natural Resources. The DNR currently manages over 5 million acres of which 2.1 million are forested. Of the 2.1 million acres of forested lands managed by the DNR, 1.4 million acres are located in western Washington (Mason 2005). These lands were mostly obtained through federal grants occurring when Washington became a state in 1889. These grants stipulated that the lands be managed and used to support specific public beneficiaries in perpetuity. Some lands have also been acquired by the state through tax foreclosures and delinquencies. These lands are referred to as Forest Board lands and are also managed in the same manner as the federally granted lands (WADNR 1997). Both federally granted land and Forest Board lands are referred to in the state of Washington as trust lands.

A trust is a relationship where one party owns or holds the title to a property and manages it for the benefit of another. In this case the state of Washington is the trustee and has designated the DNR to manage the states trust lands. The beneficiaries of this relationship include public schools, state universities, and charitable, educational, penal, and reformatory institutions (WADNR 1997). Thus these lands greatly support Washington's infrastructure and are a vital part of the state's economy.

The state manages its various land trusts according to strict guidelines. These guidelines require the DNR to manage the state owned properties in ways which maximize the long term financial benefits of all trusts. Two key documents establish the current goals and practices adhered to by the DNR in its role as manager. The Forest Resources Plan and the Habitat Conservation Plan, both address key management issues unique to the state of Washington. The Forest Resources Plan is a document that details the goals and methods the DNR is using in managing and protecting the long-term viability of its assets. The Habitat Conservation Plan (HCP) is a supplement to the Forest Resources Plan and establishes the DNR's approach to meeting the needs of endangered, threatened, and sensitive species. The HCP applies to 1.6 million acres of DNR-managed land (WADNR 1997).

The DNR's role as manager of these trusts is complex. Trust lands are managed as ecosystems, with numerous goals. Management considerations include timber revenue, ecosystem health, habitat conservation and creation, and other non-market benefits. This broad range of purpose requires the DNR to constantly stay abreast of new possibilities, and at the same time attempt to assess and alleviate future risk. A major component of the DNR's work is in maintaining an understanding of factors that influence the revenue stream generated from trust lands through the DNR's timber sale program. While private timber makes up the bulk of the timber harvested annually in Washington, the DNR is a major suppler of timber within the state. Figure 1 depicts the timber volumes harvested from each of the four largest landowner classifications in Washington annually since 1989. In 1989 approximately 842,000 thousand board feet were harvested from DNR timberlands. Harvest levels after 1989 declined each year until 1994 when they reached a low of approximately 323,000 thousand board feet. After 1994 annual harvest levels from DNR timberland fluctuated, and in 2002 approximately 457,000 thousand board feet were harvested from DNR timberlands.

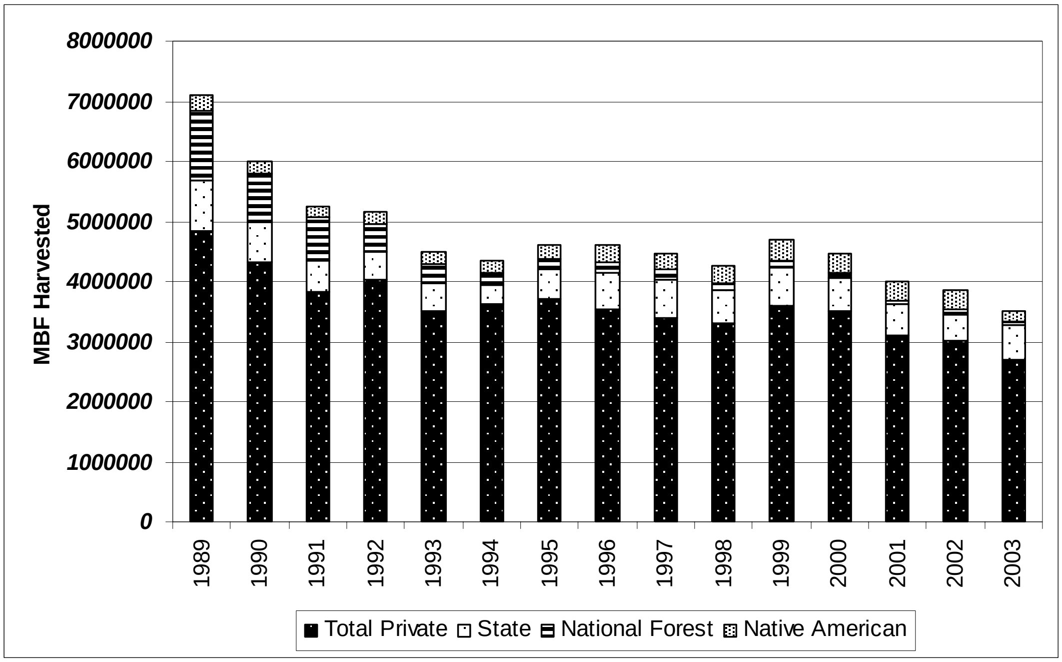

Figure 1: WA harvest volumes by landowner type. Source: WA DNR Timber Harvest Report, 2003 numbers are preliminary, 2004 and 2005 totals had not yet been published.

A BRIEF HISTORY OF THE PNW FOREST SECTOR 1989-2005

Over the study period the Pacific Northwest experienced significant volatility in its forest sector. Throughout this time period the PNW experienced supply shocks following legislation related to harvest constraints, the collapse of major export markets for wood products in Asia, and strong domestic demand for wood products in the United States fueled by strong housing markets. These major events caused large structural changes to Washington's forest sector.

The first major event impacting the PNW forest sector was the curtailment of harvest on federal, state and private landownership's in Washington. This harvest constraint began following the listing on the endangered species list of the Northern Spotted Owl (Strix occidentals caurina) in June of 1990 and the Marbled Murrelet (Brachyramphus marmoratus) in October of 1992. These listings led to curtailed harvest in the PNW and caused a supply shock that rippled throughout the industry. This supply shock was quickly followed by volatility in prices as the forest sector adjusted. This price spike was evident in timber sale values as well (Figure 2). Both the Northern Spotted Owl and the Marbled Murrelet prefer the canopy structure provided by old growth forests and thus the availability of high grade old growth timber was significantly impacted and continues to be today.

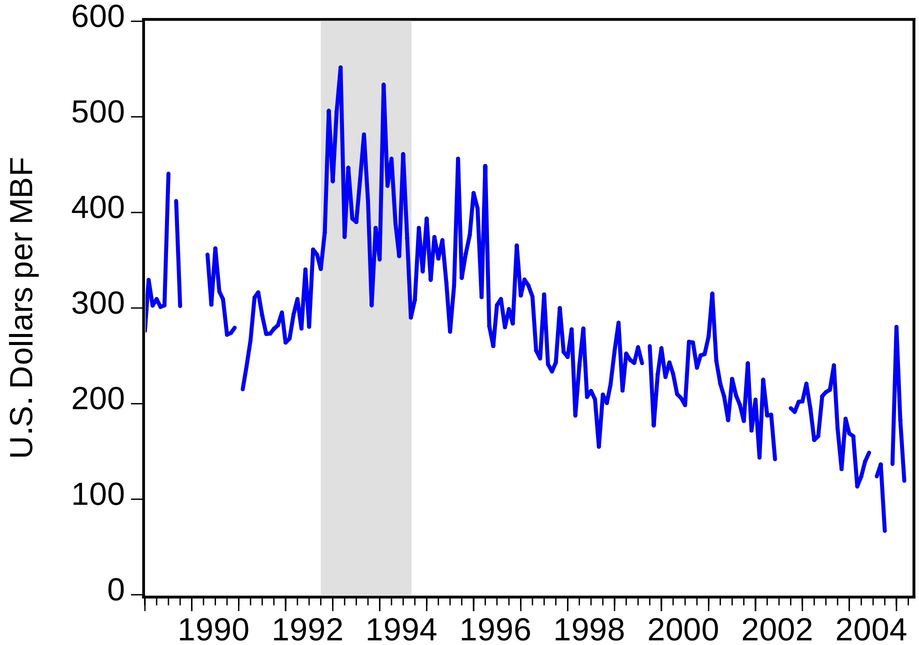

Figure 2: The average final timber sale value per thousand board feet in U.S. dollars on lump sum board sales located in western Washington. Values are real numbers adjusted using the PPI with a base of January of 1989. Highlighted period is federal timber harvest curtailment due to habitat conservation. Source: WA DNR.

The listing of the Spotted Owl and Marbled Murrelet on the endangered species list was a driving force behind the creation of the DNR's Habitat Conservation Plan. As previously mentioned this plan outlines specific management goals for the creation of habitat on DNR lands. The creation of old-growth habitat favored by the Spotted Owl and Marbled Murrelet will result in increases in stand diversity of sawtimber on DNR forested lands.

In 1997 the Asian financial crisis effectively wiped out key export markets for PNW wood products, predominately logs. The close proximity to the Pacific Rim had traditionally provided the PNW with a competitive advantage in the export of wood products to Asian nations (Perez-Garcia 2005). Specifically, Japanese markets were integral to the PNW forest products industry in its export of logs. Loss of these valuable export markets diverted increasing volumes of PNW timber to domestic markets in which the region frequently faced a competitive disadvantage to the U.S. South in servicing Midwestern and east coast markets. This change, while having important regional implications impacting the DNR as a timber supplier, can not be said to have affected the sale of state timber in the same way it affected private timber sales. Timber sold by the WA DNR has been export restricted according to the Forest Resources Conservation and Shortage Relief Act of 1990 (Daniels 2005) and must be sold to domestic commodity producers. Hence, the collapse of Asian markets did not force the DNR to seek new markets for its timber, but it may have resulted in changes to the competition it faced in domestic markets.

The housing market of the United States has been strong since 1991 and recently has been at record levels. This strong domestic demand has mitigated some of the negative forest sector impacts experienced by the PNW over the study period. The region still experienced a great deal of change, perhaps most notably in the sawmilling sector which has experienced significant structural change. The Washington state sawmilling industry has consolidated down to about 75 mills comprised of predominately large volume commodity producers (DNR Mill Surveys). Producers have improved recovery rates and adjusted their production capabilities to smaller diameter timber (Perez-Garcia 2005). By adjusting production capabilities, mills have focused their input needs on a smaller range of sawtimber classifications, making timber sales of more heterogeneous sawtimber less attractive to these producers.

REVIEW OF PAST STUDIES

In reviewing previous literature, numerous studies were found that examined the influences and characteristics contributing to the formulation of final price in the sale of standing timber. Although the studies are distributed globally, a large volume of the work examining intricacies of timber sales over the past quarter century has occurred in the southern portion of the United States, particularly North Carolina.

It was readily apparent that many different influences to timber value had been examined. Influences include competitiveness among perspective buyers, bid or auction method (verbal or sealed bid auction), appraisal price advertised prior to sale, landowner type (private or federal government), physical characteristics, contract types (lump sum versus per unit), and consultant participation. All of these variables have shown to have interesting relationships with timber value.

The effects of stand diversity on a timber sales sold price has not been extensively covered by the literature. A number of studies have attempted to forecast the effects of diversity by using inventory/growth models and examining the effects of different management plans on the relationship between stand value and tree size diversity. Stand value in this instance is calculated using forest value or soil expectation value calculations (Buongiorno et al. 1994; Buongiorno et al. 1995; Ingram and Buongiorno 1996). Literature in which timber sale history is examined for this same relationship is even less common. Boltz et al. (2002) examined the relationship between diversity and sale value by examining a history of timber sales occurring on U.S. Forest service lands in North Carolina. Their study calculates a shadow price for diversity on these sales.

It is important when examining the literature to consider what an individual study's diversity variable represents. Studies by Buongiorno and Ingram (1996), and Buongiorno et al. (1994) create a diversity variable using the Shannon-Wiener index calculated with inventory data on tree species and size class. Boltz et al. (2002) also uses the Shannon-Wiener index to create two diversity variables. One is a three group index where the grouping is hardwood sawtimber, softwood sawtimber, and pulpwood. The other is a four group index including low-valued hardwood sawtimber, high-valued sawtimber, softwood sawtimber, and pulpwood groups. The current study will formulate a diversity variable using the Shannon-Wiener index calculated with inventory data on tree species and sawtimber grade. The variable will then be included in a hedonic sale price equation in a similar manner to that used by Boltz et al. (2002).

In a related study of the effects of transaction costs on final sale value, Leffler and Rucker (1991) examined the differences between lump sum and per unit timber sales with respect to incidences of presale measurement. They hypothesized that increases in heterogeneity of a timber tract would increase the occurrence of per unit timber sales due to increased transaction costs or presale measurement that would be required if heterogeneous tracts were instead sold using a lump sum method. They defined timber tract heterogeneity as "the composition and volume of the timber on the tract". More specifically they included the percentage of hardwood sawtimber in their equation and due to its variability in value, predicted that it would increase the occurrence of per unit contracts. They did not reject this hypothesis.

The research of Leffler and Rucker (1991) does not directly examine the relationship between stand diversity and sale value, but the research findings regarding the relationships between timber tract heterogeneity, transaction costs and sale method imply that diversity of sawtimber influenced sales price in lump sum timber sales. The effects of heterogeneity were further explored in research predicting forest consultant participation. Munn and Rucker (1998) refuted the industry assumption that consultant participation has a greater probability of occurrence on high value timber sales. They instead related increases in the probability of consultant participation to greater levels of uncertainty, defined as the level of heterogeneity in a sales sawtimber.

Increases in the number of bidders on a given timber sale has been found to increase final sale price. Competition is found to be a significant factor in moving the final sale value closer to the true market value. Theoretically in a competitive auction framework the final price paid is the second highest below true market value. This follows the line of thought that a winning bid in a competitive framework is the true market value less the future costs faced by the buyer. Haynes (1980) found that the incidence of overbid, the difference between final bid price and the minimum bid price, increased with the addition of bidders. Inclusion of the number of bidders participating in examinations of past timber sales is routinely found to have strong significance (Haynes 1980; Sendak 1991; Carter, Newman 1998; Boltz et al. 2002).

The physical characteristics of a timber sale are the most powerful in explaining the final sale price. They comprise the bulk of the calculations used in appraisal methods such as transaction evidence appraisal and multiple regression analysis, which establish the appraisal or advertised price. Information detailing physical characteristics is typically made available to the buyer ahead of time. The buyer interprets the species and grade of timber in a sale and uses this information to determine the bid price that they are willing to offer. This is the same information the consultants, landowners, and government agencies use in determining a minimum price. All methods of appraisal encountered in this review of the literature used some form of timber sales physical characteristics to establish either a minimum bid price or an estimation of true market value. The level of detail regarding a sales physical composition depends on the focus of the study. In their multiple regression model for estimating stumpage value for tax purposes, Bare and Smith (1999) use variables that are species and grade specific. In some cases they group similar grades together, but in general maintain a high level of detail regarding the physical composition. In contrast, studies examining independent variable impacts to stumpage price other than physical characteristics often create broad aggregate groups such as the stocking of high and low valued hardwood and softwood timber in a given sale (Leffler and Rucker 1991; Sendak 1991; Munn and Rucker 1995; Munn Palmquist 1997; Munn and Rucker 1998; Carter and Newman 1998; Boltz et al. 2002; Huebschmann et al. 2004). This method allows the researcher to account for physical characteristics of a sale while focusing on how sale value is affected by other factors such as stand diversity, cost structure, or landownership classification.

The literature varies in findings regarding the impacts of parcel size on timber sale value. Most studies include a variable for total area in acres or hectares, but this variable is not consistently positive or negative with respect to its influence on sale value. Some research has found that increases in parcel size result in greater final sale values (Carter and Newman 1998). However, it is not uncommon for studies to find significant evidence that increases to parcel size negatively affect final sale value (Munn and Rucker 1995; Boltz et al. 2002). The presence of economies or diseconomies is not consistent across the literature. This may be due to regional characteristics or other factors such as landowner types and regulations associated with those land ownerships. In some cases it may be closely correlated with other variables such as road costs and the density of the timber. In any case, the literature clearly states that it is important for researchers to consider how sale size impacts the results of the empirical study of timber sales.

MODEL CONSTRUCTION AND DATA ANALYSIS

The neoclassical theory of production which assumes homogeneity of individual factors of production is not an appropriate theoretical application when considering timber used as an input for the production of lumber. As inputs in the production of lumber, timber sales can not be considered homogeneous. Timber sales have unique characteristics like volume, area, species make up, quality class, and costs associated with harvest. Thus a hedonic price function defining the price of a heterogeneous input as a function of the inputs characteristics is more appropriate. Prior research explained that using a hedonic price function, a timber sale could be described as differentiated factors of production associated with products produced from timber (Puttock et al. 1990, Lippke 1993, Munn and Palmquist 1997, Bare and Smith 1999). The hedonic method was originally developed for applications in consumer choice theory (Rosin 1974). It was adapted by Ladd and Martin (1976) for application to heterogeneous production inputs, specifically corn as an input in the production of various food stuffs. This application was expanded to the analysis of timber sales as input in the production of lumber by Puttock et al. (1990). The following explanation of the underlying theory is a review of the work of Puttock et al. (1990).

THE HEDONIC PRICE MODEL

Demand factors of production are represented by the first order conditions of profit maximization when homogenous inputs are used. Equation 1 represents the profit function of a firm in perfect competition with a single output, L, and input X.

$$\pi = P_L * f(X) - P_x X \qquad (1)$$

Equation 2 represents the first order conditions for profit maximization with respect to the input X.

$$d\pi / dX = P_L(df/dX) - P_x = 0 \qquad (2)$$

If we then solve for P_x equation 3 follows.

$$P_x = P_L(df/dX) \qquad (3)$$

The marginal yield of the input in the production of L is represented as (df/dx). The right-hand side of equation 3 is the marginal value product of input X. Equation 3 represents the factor demand for the input X.

While the theory above is appropriate for instances of homogeneous production inputs, for a heterogeneous input like timber used to produce lumber, the inputs impact on production will depend on the amounts of the various characteristics that the input contains. In the case of producing a single output, L, from a heterogeneous input the following equation defines the profit maximizing equation for a competitive firm.

$$q_L = F(V_1, V_2, \cdots V_n) \quad (4)$$

The quantity of product L is represented in equation 4 as qL. The quantity of the input characteristics are represented by Vj (j = 1, 2, . . . n). If the input characteristics Vj are assumed to be purchased in units of X, there are many possibilities for the unit value of X with respect to a timber sale. X could be in units of the total acreage of a sale, or perhaps the total volume of timber sold. Similar to the approach of Puttock et al., this study focuses empirical work on the timber sale value, which allows the units of X to be unspecified. If X is considered a single input with an n-dimensional vector of sale characteristics, used in the production of L, with P_L and P_X as the output and input prices of L and X, the following equation represents a firm's profit function.

$$\pi = P_L * F(V_1, V_2, \cdots V_n) - P_x X \; ; \; j = 1 \cdots n \quad (5)$$

The first order conditions for profit maximization follow.

$$d\pi / dX = P_L \sum_j (\delta F / \delta V_j)(dV_j / dX) - P_x = 0 \quad (6)$$

If we then solve for PX we obtain the following equation.

$$P_x = P_L \sum_j (\delta F / \delta V_j)(dV_j / dX) \quad (7)$$

In equation 7 (dV_j / dX) represents the marginal yield of X to the jth characteristic used in production. The marginal physical product from one unit of characteristic j is represented as $(\delta F / \delta V_j)$. Finally the value of the marginal product of the jth characteristic of input X in producing L is $P_L(\delta F / \delta V_j)$. Equation 7 can be simplified in two ways. First the assumption is made that $(\delta F / \delta V_j)$ is constant and represented as β_j. Next a second assumption is made that the quantity of characteristics j is proportional to the number of units of X. In other words, $V_j = \theta_j X$ and thus,

$$(dV_j / dX) = \theta_j = \frac{V_j}{X} \quad (8)$$

Under these assumptions equation 7 becomes,

$$P_x = P_L \sum_j \beta_j \frac{(V_j)}{X}. \quad (9)$$

Finally, multiplying through by X yields the following equation.

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

The dependent variable in this study is defined as the final timber sale value in DNR lump sum, sealed bid, Board timber sales occurring in western Washington. In the regression equation outlined in the next section the dependent variable is represented as MV, short for market value. This variable is represented in equation 10 as P_xX. Equation 10 defines the final sale value as equal to the sum of the marginal value products, $P_L \beta_j$, of each characteristic multiplied by the total quantity of each characteristic, V_j, in that individual timber sale. It is important to note that equation 10 assumes homogeneity of degree 1 in the price of lumber, P_L. This assumption is relaxed in the empirical estimation of the model, where a regional lumber price index is used corresponding to the date of sale as a proxy for output price.

EXPLANATION OF DATA

The dataset used to conduct this research was obtained through a data sharing agreement with the Washington State Department of Natural Resources. The master dataset is a Microsoft Access spreadsheet containing a detailed record of the timber sales from DNR lands. The period of sale history covered from July of 1987 to September of 2005. This historical record included three sections of information related to each individual timber sale. The first section provided inventory characteristics, the second related to cost and harvest ramifications, and the third section provided financial information regarding the result of a given sales auction date. The sections were linked together through a common identification number to create a spreadsheet where each entry represented an individual sale with information from all three sections. This spreadsheet consisted of approximately 4027 individual timber sales.

The database was pared down to make it more usable in statistical analysis. The first adjustment was to maintain only timber sales occurring in western Washington. This area is defined as counties west of the crest of the Cascade Mountains. In forests of Washington this area represents the greatest forest value and was of the most interest. Next, timber sales that had used a bid method other than sealed bid were eliminated. This action was taken to control for the possibility of different bid methods affecting the bid strategy of prospective buyers and thus final sale value. The current study was not concerned with investigating the difference between bid methods and the resulting bid strategies so only entries for timber sales that had been sold by sealed bid were retained. The sealed-bid method is commonly used by the DNR and the elimination of the non-sealed bid sales left 3597 timber sales in the dataset.

Next the salvage and pole sales, which are typically used for forest health purposes, were removed from the data. Contract harvest sales were also removed. In contract harvest sales the timber is harvested for the purpose of improving forest health. These logs are taken to a decking site and grouped into bundles commonly referred to as log sorts (Mason 2005). These log sorts represent bundles of timber that DNR managers expect to be attractive to prospective buyers. Instead of bidding on the right to harvest all timber and thus all sorts comprising a given lump sum sale, bidders have the opportunity to bid on only the timber of interest. Initially these sales were of great interest so that the differences between revenue generated by lump sum and contract harvest sales could be examined. However, the data pertaining to the contract harvest sales was neither detailed enough nor prevalent enough to fit the models developed by this study. Additionally, key differences in methodology made comparisons questionable. The DNR uses the contract harvest method to provide necessary treatment to improve forest health in areas previously cost prohibitive. These issues created problems with respect to research design and led to the removal of contract harvest sales from the dataset with the hope of future research into the results of this fledgling state program.

Finally timber sales containing incomplete information were removed from the database. This resulted in the elimination of sales occurring in 1987 and 1988. Data recording methods during this time period were not consistent and resulted in numerous incomplete entries. All timber sales left in the dataset were Board sales, or timber sales approved by the Board of Natural Resources. This final paring yielded an organized dataset spanning the time period from January of 1989 to May of 2005. The final dataset contained 2194 entries over this time period, each with information on an individual sealed bid, Board timber sale occurring in western Washington.

Four additional statistics were added to each entry for the purpose of estimating the model. The monthly price index for Douglas fir lumber in the PNW was obtained from the Western Wood Products Association (WWPA). Then three indices which measured the sawtimber diversity of each sale were added to the data. Three indices were calculated for each individual timber sale entry using the Shannon-Wiener Index calculation and are explained in detail in the following section. Finally, all values were deflated using the Producers Price Index of lumber. The study periods initial period, January 1989, was selected as the base period.

THE DIVERSITY VARIABLE

The diversity variable was created to facilitate examination of the impact increased heterogeneity of sawtimber in a tract has on the final sale value of lump sum timber sales. This required the calculation of a tailor-made variable that would account for the species and grade characteristics of each individual timber sale. To this end the Shannon-Wiener Index was selected as the best method for calculating this variable.

Buongiorno et al. (1994) and Boltz et al. (2002) successfully used the Shannon-Wiener Index as a measure of stand diversity. It is a measure of order within a system developed by information theory. It was an appropriate choice for this data because it could be calculated using the detailed inventory information. In this research stand diversity or heterogeneity applied only to the species of trees and log grades that were included in the timber sale data. Wildlife and other facets of a timber stand were not included in the calculation of the diversity index.

Each sale in the final dataset contained information about the volumes of sawtimber found in the sale. The volumes of sawtimber in each timber sale were organized into five grade classes. The highest grade class was an aggregate class comprised of the volume of P, 2P, 3P, SM, and #1 sawlog grades. The other four grades were composed of the volumes of #2, #3, #4, and #5 sawlog grades present in a given sale. The maximum amount of species classes found on any given sale was eight; this was used as a maximum in the creation of the index. Thus, in this calculation the system was the individual timber sale and the order being measured was the distribution of timber volume among species and sawlog grade types.

The Shannon-Wiener Index was calculated using the following equation.

$$D_{mn} = -\sum_{m=1}^{n} p_{(ij)} \ln p_{(ij)}$$

Where,

$P_{(ij)m}$ = *The proportion of volume in the ith grade occurring in the jth species relative to the total sale volume in sale m.*

n = *The number of possible species multiplied by possible grades* = 40.

D_{mn} = *The diversity index of sale m, for n.*

The equation is tailored to the species and grade classification parameters provided in the dataset. It implies that a perfectly heterogeneous timber sale would have an even distribution of volume within in each of five grades across each of eight species. This hypothetical situation would thus entail an even distribution across forty categories. This situation of maximum diversity is represented,

$$\ln(n) = \ln(40) = 3.689$$

Thus, the diversity index created had a range of 0 for a completely homogeneous timber sale to 3.689 for a completely heterogeneous timber sale. It is readily apparent that a completely heterogeneous timber sale according to these parameters is neither feasible nor desirable. However, this index allows for a uniform calculation of a diversity measure for each individual timber sale. The creation of this variable allows for the empirical estimation of the effect increasing levels of heterogeneity of sawtimber, by this definition, has on the final sale value. Figure 3 displays a histogram of the distribution of diversity values found in the timber sale history.

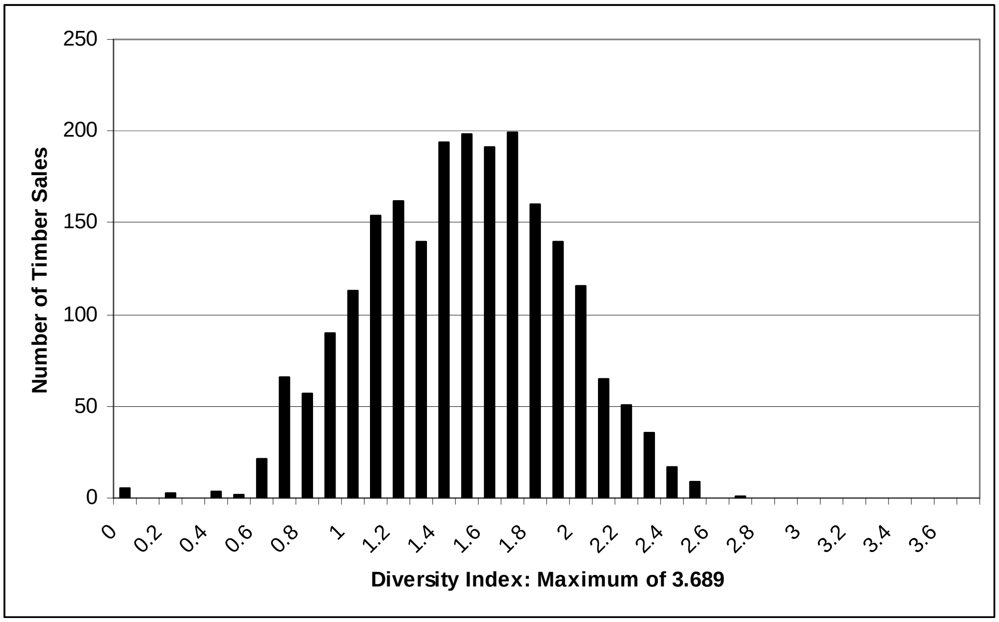

Figure 3: Histogram of the diversity index. The index has a maximum value of 3.689.

To examine the individual effect of the distribution of volume of both grade and species on the market value of a timber sale, the Shannon-Wiener Index above was adapted into two additional indices. A species specific index was calculated that measured the distribution of volume among the eight possible species. It had a range from 0 for a perfectly homogenous stand to 2.08 for a stand with volume distributed equally among all eight species. A grade specific index was calculated that measured the distribution of volume among the five grade classifications. It had a range from 0 for a perfectly homogeneous sale to 1.61 for a sale with volume distributed equally among all five grade classifications.

THE REGRESSION MODEL

The database used for this study was comprised of only DNR lump sum, sealed bid, Board sales in western Washington. Timber sales in this dataset were uniform in the information available to interested buyers due to the agencies regulations on timber sale procedure and thus a hedonic model was appropriate in the analysis of factors impacting a timber sales market value. The initial model proposed as an approximation of the true underlying, but unknown functional form follows. This initial model was tested first and then adapted to better fit the data through the inclusion of different variables and by performing transformations on the independent variables.

MV = f (DIV, NBID, ACRES, CL, RDCON, RDRECON, VS1DF, VS2DF, VS3DF, VS1WH, VS2WH, VS3WH, OVOL, DFP)

Where:

MV is the final sold value of the timber sale in U.S. dollars.

DIV is the diversity measure of the timber sale.

NBID is the total number of bidders on a timber sale.

ACRES is the total acreage of the timber sale.

CL is the contract length of the timber sale.

RDCON is the total number of miles of required road construction.

RDRECON is the total number of miles of required road reconstruction.

VS1DF is the Douglas fir volume of the sawlog grades P, 2P, 3P, SM, 1S.

VS2DF	is the Douglas fir volume of the sawlog grade 2S.
VS3DF	is the Douglas fir volume of the sawlog grade 3S.
VS1WH	is the Western Hemlock volume of the sawlog grades P, 2P, 3P, SM, 1S.
VS2WH	is the Western Hemlock volume of the sawlog grade 2S.
VS3WH	is the Western Hemlock volume of the sawlog grade 3S.
OVOL	is all other volume included in the timber sale.
DFP	is the WWPA lumber index price of Douglas fir.

During the process of model fitting the following variables were also included in various combinations detailed later in this publication.

SPECIES	is a diversity measure of the timber sale accounting for only the distribution among eight possible tree species.
GRADE	is a diversity measure of the timber sale accounting for only the distribution among the five possible sawlog grades.

Explanation of Variables and Hypothesized Effects:

The dependant variable of this model was the final sold value of a timber sale in U.S. dollars. It is represented as MV, short for market value. It represented the winning bid of a timber sale. By including the volume found in the three highest grades of both dominant and co-dominant species, as well as the other sale volume and thus, total volume on the right hand side of the equation the problem of scale with respect to the dependant variable was alleviated. In other words, the existence of large bid values skewing estimates simply due to large volumes was eliminated. Previous studies have often used the winning bid per volume of timber as the dependent variable. However, in this case the inventory data made the functional form outlined above possible. The dependent variable is adjusted to the base period of January 1989, as are all dollar figures in this study, using the Producers Price Index for lumber.

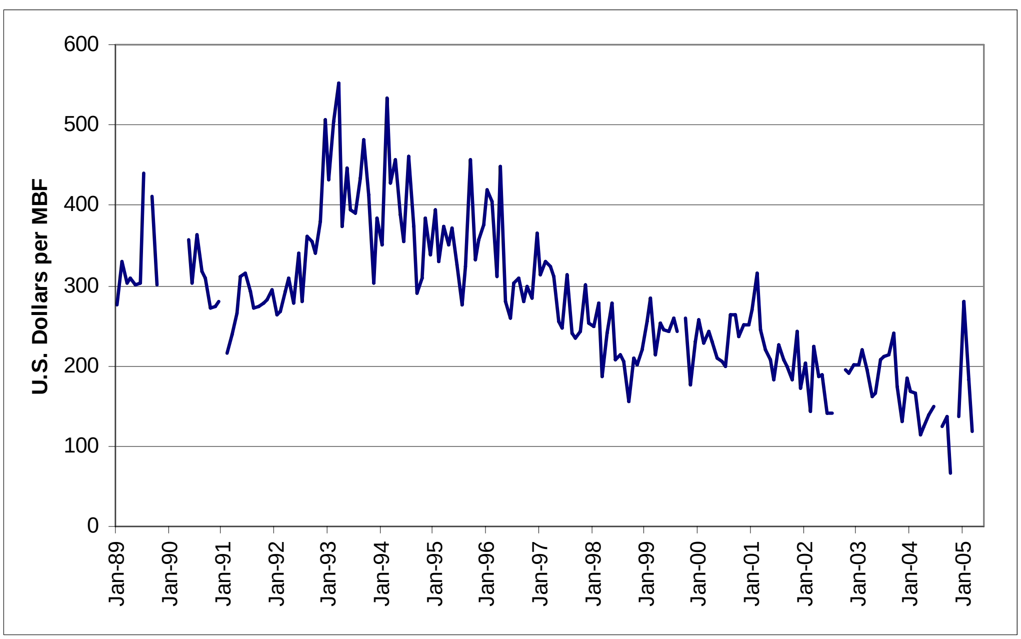

Figure 4: The winning bid per total volume (MBF). This graph displays averages for each month. Some months contained no sale data. Values are real numbers adjusted using the PPI with a base of January of 1989. Source: WA DNR.

Independent variables were selected to represent the sale characteristics that determined final sale price. These variables represented sale characteristics such as volume, area, species make up, quality class, costs associated with harvest and market conditions at the time of sale. They were hypothesized to influence the dependant variable either positively or negatively.

The first independent variable, DIV, is a measure of diversity. It was created by calculating a Shannon-Weiner Index value for each timber sale. Studies have demonstrated and implied that higher levels of sawtimber heterogeneity negatively impact the market value of timber sales (Leffler and Rucker 1991, Boltz et al. 2002). The diversity variable has a possible range from zero for homogenous stands to a maximum value of 3.689 when timber volume in a sale is evenly distributed among all species and log grades. It was predicted that increasing levels of the diversity variable would negatively impact the dependant variable due to increased transaction and processing costs associated with the purchase of more heterogeneous timber sales. These costs include the harvesting, sorting, and milling of heterogeneous sawtimber as well as the re-selling of unwanted sawtimber.

The second independent variable is NBID, or total number of bidders on a particular sale. Sendak (1991) and Carter and Newman (1998) showed that increased competition results in higher market value. Each individual timber sale found in the data set had a record for the exact number of firms that placed a bid. This is important information in relating the competitiveness of a sale to its attributes. In fair markets increasing levels of competition should theoretically increase the final sold value of timber sales. For this reason, increases in the competition for an individual timber sale, or in other words increases in the number of bidders on a given timber sale, was hypothesized to impact the dependant variable positively.

Total acreage is an independent variable of the model represented as ACRES. This is a variable that has been found to have different effects on the dependant variable. Economic theory suggests that economies of scale resulting from the purchase of larger timber tracts will lead to lower production costs of timber harvest. This leads to the expectation that larger timber tracts will positively influence the dependant variable. Munn and Rucker (1995) and Carter and Newman (1998) found this thought pattern to be true. However, a study by Boltz et al. (2002) found a negative relationship between final sale value and increasing size of timber tract. They attribute their finding to "higher transactions costs associated with larger timber tracts, which may depress the number of bidders for a given sale and inflate expected production costs." Due to the detailed sale information provided by the DNR to all prospective buyers, transaction costs are not expected to influence the buyers choice on whether to bid on a sale or not. For this reason total acreage was hypothesized to follow traditional theory regarding economies of scale and positively impact the dependent variable.

The fourth independent variable in the equation is contract length, CL. This corresponds to the number of months from the date of sale that the purchasing firm had in which to complete harvest on that timber tract. A longer contract period allows a firm additional time in which to strategically harvest timber at least cost. Most firms have numerous timber tracts under contract at a given time and a longer contract length permits them flexibility in determining the use of their assets. It was believed that longer contract lengths would positively impact the dependant variable.

The construction of roads to facilitate harvest is a necessary and costly endeavor incurred by the bid winner. These road costs are represented by the variables RDCON and RDRECON. RDCON represents the miles of mandatory road construction and RDRECON represents the miles of mandatory road reconstruction required by the sale contract. The building of roads is a costly and time consuming expense that firms will view negatively. Firms will adjust their bidding strategies accordingly to reflect road construction costs. Greater mileage of required road construction and reconstruction was believed to negatively impact the dependant variable.

The volume variables represent total sawlog volume sold in each sale. The three highest sawlog grades of the dominant and co-dominant species were represented as well as all other volumes found in each timber sale. The VS1 grade is an aggregate of the sawlog grades P, 2P, 3P, SM, and #1 sawlog grades. The other grades, VS2 and VS3 correspond to the #2 and #3 sawlog grades respectively. The volumes for these grade classifications are included for the dominant and co-dominant species, Douglas fir (Pseudotsuga menziesii) and Western Hemlock (Tsuga heterophylla). The combined volume of these grade classes in the dominant and co-dominant species averaged 73 percent of the total sale volume on a given timber sale. The other volume variable, OVOL, contained the Douglas fir and Western Hemlock volumes in the #4 and #5 sawlog grades as well as all volumes of other species. By including all of these variables the total volume of the sale was represented. These are essential variables used in most timber sale appraisal techniques. The effects on final sale value are common knowledge; higher grade classes more positively influence the dependent variable. However, the inclusion of these variables is an important part of model estimation due to the fact that they are the drivers of final sale value and key components in the vector of sale characteristics of the hedonic price model. While their effects were not the focus of this study, their inclusion was necessary as without them assessments of other variables like sawtimber diversity, road costs, number of bidders, and total acreage would not be possible.

The Douglas fir lumber price index, DFP, is an independent variable included to measure lumber market activity over the study's time period. This variable is an index price of Douglas fir lumber (the most dominant and demanded species found in sales occurring in this region) in the month of sale. Examination of harvest levels by species from DNR land located in western Washington clearly showed Douglas fir to be the dominant species. Hemlock commanded the next largest share of the total harvest (Figure 5). This relationship among timber species is also found in the data specific to Board sales.

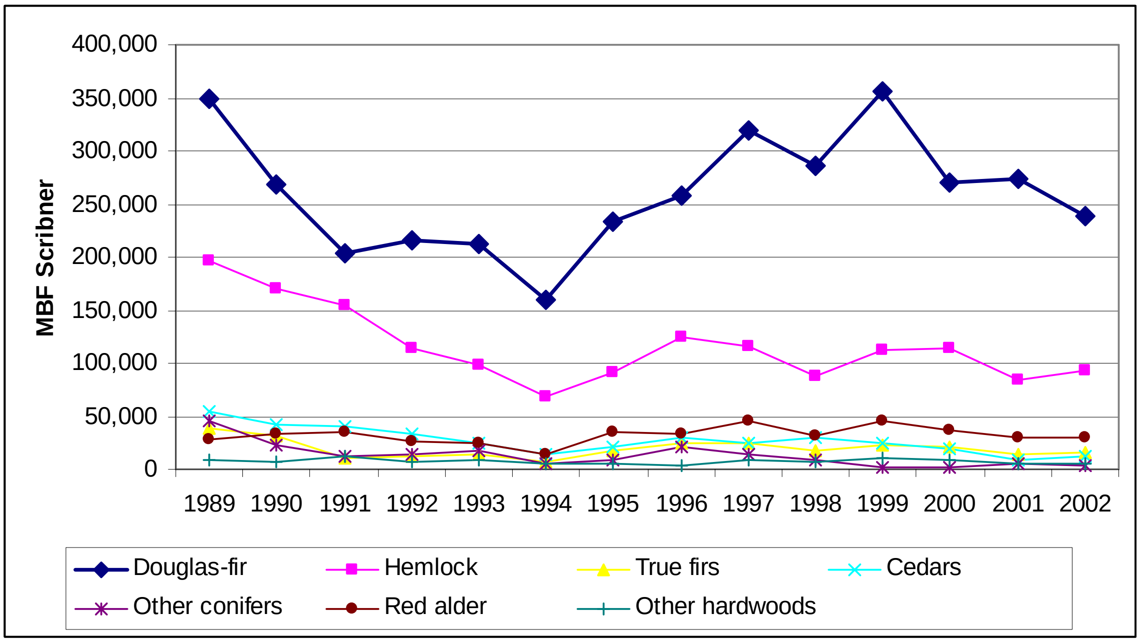

Figure 5: Western Washington DNR harvest volumes (MBF) by species 1989 through 2002. Source: WA DNR Washington Timber Harvest Report.

The Douglas fir lumber price index variable was taken from the lumber index published by the Western Wood Products Association (WWPA). This is a regional lumber price index that is indicative of movements in the lumber markets of the Pacific Northwest. The regional nature of this index made its application appropriate due to the regional nature of the majority of bid winners on DNR timber sales. Figure 6 displays the movements in the Douglas fir index as well as the Hemlock-fir index produced by the WWPA. While both indexes were considered applicable, the Douglas-fir index was selected. In theory it would be desirable to include both so that lumber prices for both the dominant and co-dominant species would be included. However, Figure 6 displays how closely these prices have moved over the study period. This resulted in a collinearity issue that was resolved by selecting the Douglas fir index. The index is adjusted to the base period of January 1989 using the Producers Price Index for lumber. Rises in the index were predicted to positively influence the dependent variable.

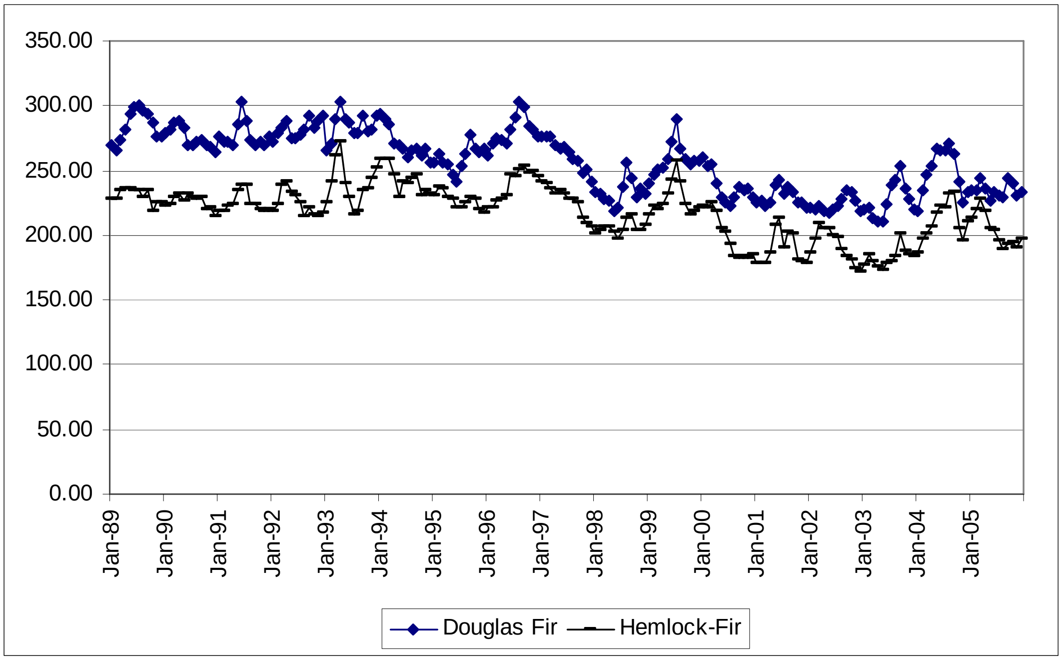

Figure 6: WWPA lumber price index for Douglas fir and Hemlock fir. Values are real numbers adjusted using the PPI with a base of January of 1989. Source: Western Wood Products Association.

Finally, in later estimations of the model the diversity variable was recalculated into two variables, SPECIES and GRADE. Both were calculated using the Shannon-Weiner Index previously mentioned. SPECIES is an index variable that measures only the distribution of volume among species types in the model. The index was created with the assumption of a possible eight species on a sale, which gave the index a range from 0 for a homogeneous sale, to 2.08 for a perfectly heterogeneous sale with respect to timber species. GRADE is an index variable that measures the distribution of volume among the five grade classifications previously mentioned. It has a range of 0 for a homogeneous sale, to 1.61 for a perfectly heterogeneous sale with respect to grade classification. These variables were created as an alternative to the original diversity variable to help the researcher determine whether the species or grade distribution was having a stronger effect on the dependent variable. Both SPECIES and GRADE were predicted to negatively impact the final sale value.

EMPIRICAL MODEL ESTIMATION

The initial model was a linear model estimated using ordinary least squares (OLS). The dependent variable was the winning bid in units of U.S. dollars. The independent variables were those previously listed in the description of the hypothesized underlying functional form of the model. The Windows-based statistical software E-views was used to analyze the data which contained a total sample of 2194 timber sales to be analyzed. Seven models were estimated. Detailed output of each model is available in the appendix. Table 1 displays the most pertinent information produced by the first five models detailed in this section.

Table 1: Estimation output for models 1 through 5. Bolded values are coefficients. Values in italics are t-statistics. * P<= 0.01, ** P<=0.10, *** P>0.10, all other P-values are equal to 0.00.

	Model 1	Model 2	Model 3	Model 4	Model 5
DIV	-59218.05	-58965.17	-60614.76	-187194.63	-53928.05
	-4.57	-4.55	-45.03	-20.30	-29.12
DIV^2				48054.00	
				15.65	
NBID	21587.10	21525.29	22076.63	40266.54	36713.23
	11.14	11.10	87.66	57.82	49.01
NBID^2				-1661.79	-1369.66
				-24.35	-23.06
ACRES	-1084.30	-1095.17	-1093.84	-704.14	-670.95
	-14.70	-14.89	-80.73	-34.39	-45.70
ACRES^2				-0.36	-0.32
				-15.11	-16.28
CL	-1109.06				
	-1.72**				
RDCON	-978.94	-985.98	-957.63	-1164.72	-1109.66
	-6.06	-6.11	-56.63	-108.16	-42.41
RDRECON	-264.64	-271.20	-258.19	-309.33	-316.55
	-4.06	-4.16	-31.42	-24.44	-25.34
VS1DF	769.59	768.68	769.70	640.30	644.75
	29.69	29.65	221.96	78.24	99.96
VS1DF^2				0.12	0.10
				12.23	9.87
VS2DF	337.01	336.56	335.86	361.44	361.59
	47.39	47.34	279.65	148.62	142.32
VS2DF^2				-0.01	-0.01
				-8.10	-7.11
VS3DF	282.45	281.35	279.71	316.46	318.16
	20.42	20.35	166.86	90.24	86.68
VS3DF^2				-0.02	-0.03
				-18.13	-15.95
VS1WH	976.10	974.88	1034.25	986.30	956.95
	12.58	12.56	25.76	47.80	53.12
VS2WH	220.59	221.74	224.63	222.25	229.31
	10.55	10.61	77.94	51.73	70.91
VS3WH	135.06	133.20	130.19	128.80	120.59
	8.29	8.19	68.90	59.29	36.31
OVOL	258.06	256.72	256.61	254.79	254.16
	41.29	41.38	499.32	209.34	126.04
OVOL^2				-0.0001	-0.0006
				-0.51***	-2.56*
DFP	3765.91	3712.78	3698.85	3718.65	3787.23
	16.58	16.49	146.28	152.24	177.79
Adjusted R-squared	0.85	0.85	0.85	0.86	0.86

The output of the initial estimation (model 1) raised some interesting points. All variables were significant at the 5 percent level of significance except the variable for contract length. This variable corresponded to the contract length in months or in other words the time a buyer had to harvest the timber they purchased. The coefficient of contract length was positive as predicted, but the variable was highly insignificant. A recent purchaser's survey found that most preferred a contract length of three years (Mason 2005). However, while this may be preferred among log buyers, the initial model does not show evidence that contract length was a constraint to the bidding behavior of timber buyers.

Next the contract length variable was removed and model 2 was estimated. A graph of the residuals with respect to predicted market values led to suspicion of heteroscedasticity (Figure 7). To test for the presence of heteroscedasticity, White's test was performed with cross terms included. White's test is a large sample Lagrange Multiplier test for heteroscedasticity. Unlike other tests for heteroscedasticity like the Breusch-Pagan test, it requires no prior knowledge of the cause of heteroscedasticity and does not depend on assumptions of normality. The output showed strong evidence to refute the test's null hypothesis of homoscedastic error terms.

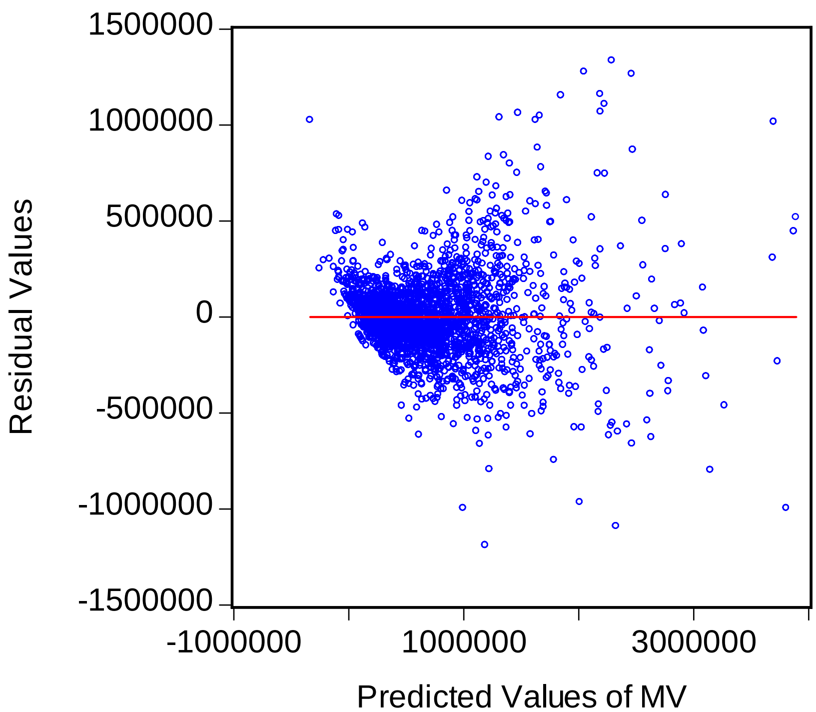

Figure 7: Scatter plot of the residuals of model 2 over the predicted values of the final timber sale value.
Figure 7 above implies that the larger sales had larger variances. Timber sales that have large final bid values are generally larger sales in both volume and acreage. These larger timber sales have greater variability in sale attributes. Although even with the presence of heteroscedasticity the estimates of the model are unbiased and consistent, violations of the Gauss-Markov theorem influenced the decision to correct for this issue.

The method used to correct the heteroscedasticity of the model was a weighting procedure termed feasible-generalized least squares. The squared residuals of model 2 were regressed against all independent variables, variables squared, variable cross terms, and a constant to produce fitted values of the residuals. In instances where the fitted values of the residuals were less than or equal to zero the squared residual values of model 2 were substituted. Model 2 was then estimated using OLS with a weighting of 1 over the square root of the adjusted fitted residual values. This procedure resulted in homoscedastic error terms and model 3.

All variables of model 3 were highly significant at the five percent level of significance. Model 3's Adjusted R-squared value of 0.85 indicated that 85% of the variation in final sale value was being estimated by the independent variables of the regression equation.

DIV, the diversity variable in this model had a negative coefficient. This variable was also highly significant with a p-value of 0.00. Model 3 indicated that increases in the diversity of sawtimber among species and grades decreased the final sold value of a timber sale. The marginal effects of this variable are important in understanding how the DNR markets and manages its timber sales. A one unit increase in diversity decreased the dependent variable by $60,614.76 on average.

Model 3 shows a positive relationship between the number of bidders and timber sale value. This was as predicted and in keeping with the literature. This variable provided a clear example of the positive effect that increased competition has on the dependent variable. Model 3 stated that on average, the addition of another bidder on a timber sale results in an average increase of the final sale value of $22,076.63.

Total acreage is a variable that the literature reports as having both positive and negative relationships on the dependent variable. Its impact on final sale value appears to be specific to the study area. In model 3, total acreage was hypothesized to have a positive affect on the dependent variable. In estimating the model this hypothesis was refuted. The coefficient of total acreage was negative. Model 3 stated that an increase of the parcel size by one acre resulted in an average decrease of the final sale value by $1093.84. The model indicated that economies of scale were not present on DNR timber sales of the dataset.

Both road construction variables showed the predicted negative relationship in model 3. An additional mile of required road construction resulted in an average decrease of $957.63 in the dependent variable. An additional mile of required road re-construction decreased the dependent by an average of $258.19. The miles of required road construction had a greater impact on the dependent variable. This is a logical representation as road re-construction can generally be considered less costly than new construction and would be expected to influence buyer's prospective bids less.

All variables representing timber volumes positively impacted the dependent variable. The high-grade aggregate classes had the greatest impact at the mean and were followed successively by the other grade classes. All other volume variables had smaller coefficient values, but positively increased the dependent variable. The price variable of Douglas fir lumber had a positive relationship with the dependent variable in the model. Model 3 stated that as regional lumber prices in the PNW increased, buyers were willing to offer higher bids for stumpage sales.

FURTHER EMPIRICAL WORK

To this point the regression equation had been strictly linear. However, graphical analysis of the raw data to examine the relationships of the independent variables with the dependent did not support linear relationships for all variables. Figure 8 displays the relationships between market value and the number of bidders (NBID) as well as diversity (DIV). By examining a scatter plot of the raw data and including a line of nearest fit it was apparent that both of these variables might have been better represented in the regression equation as quadratic terms. Examination of similar raw data plots for total acreage, other volume, and all three variables for the volumes of Douglas fir also influenced investigation of quadratic terms for these variables.

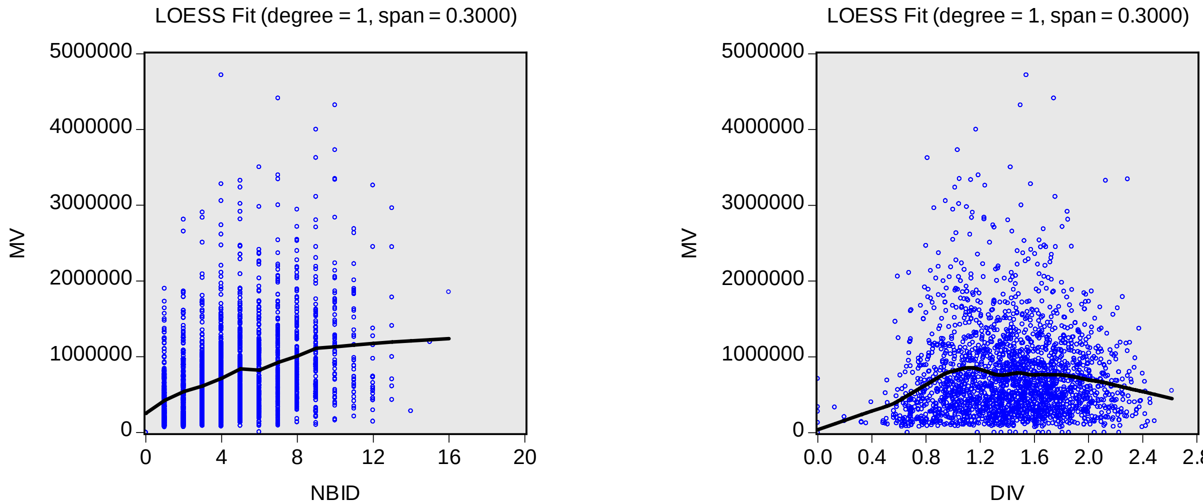

Figure 8: Raw data analysis of the relationship of DIV and NBID to MV. These are scatterplots of the actual data with a line of nearest fit included.

Next the regression equation was estimated with quadratic terms for diversity, number of bidders, acres, all Douglas fir volumes, and other volume. This estimation (model 4) was again weighted to correct for the presence of heteroscedasticity. The quadratic coefficients yielded relationships that corresponded to those observed in the examination of the raw data with the exception of the diversity variable. In Figure 8 the raw data plot displays a relationship of market value increasing at a decreasing rate with increases in the diversity variable. This eventually resulted in the diversity variable negatively impacting the market value of a timber sale. However, the coefficients of the quadratic term for diversity returned by model 4 stated that market value decreased at an increasing rate with increases in the diversity variable. This was the opposite of the relationship observed in Figure 8. For this reason the use of a quadratic term for the diversity variable was rejected and it was concluded that the best representation of the diversity variable in the regression equation was as a linear term. Another model (model 5) was estimated with quadratic coefficients for the number of bidders, acres, the variables for the volume of Douglas fir, and other volume. All other terms in the estimation were linear. Model 5 was again weighted to correct for heteroscedasticity.

Model 5 also returned a negative coefficient for the diversity variable, DIV. DIV was highly significant with a p-value of 0.00. Model 5 stated that at the mean a one unit increase of diversity would on average, result in a loss of $53,928.05 in market value.

The quadratic term for the number of bidders returned a relationship of increases to market value with increases in the number of bidders at a decreasing rate. At the mean the effect of an additional bidder on market value was an increase of $35,343.57.

The quadratic term for acreage stated that increases in the total acreage decreased the market value at an increasing rate. At the mean model 5 reported an average loss to market value of $671.28 with the addition of another acre.

Model 5 also returned negative coefficients for both road construction variables. An additional mile of road construction on average resulted in a loss to market value of $1109.66. An additional mile of road reconstruction on average resulted in a loss in market value of $316.55.

All variables representing timber volumes positively impacted the market value in model 5. The high-grade aggregate classes again had the greatest impact at the mean and were followed successively by the other grade classes. The quadratic term for high-grade Douglas fir showed that increases in the volume of high-grade Douglas fir present in a timber sale increased the market value of the sale at a slightly increasing rate. The volumes of Douglas fir #2 and #3 sawlogs as well as the other volumes on average increased the market value at a slightly decreasing rate. These results were in keeping with the graphical observations observed in the raw data. The price variable of Douglas fir lumber had a positive relationship with the dependent variable in the model.

With its inclusion of quadratic terms model 5 was a slight improvement over model 3 with a slightly higher adjusted R-squared value. Model 5 was chosen as the final model because it contained quadratic terms for some variables that did return relationships with market value similar to those observed in the raw data.

Model 5 reported that at the mean a unit increase in DIV resulted in on average a loss of $53,928 in market value of the sale. Considering that this diversity variable has a possible range of 0 to 3.689 a one unit change is a large and relatively abstract increment. Table 2 provides a tabular representation of what one unit changes to the diversity variable look like on average in the data.

Table 2 displays the percentages of average volume found in the 40 categories of the diversity variable. These percentages were created by averaging the volumes in each category for all timber sales that had a particular index value for DIV. Three matrices pertaining to specific diversity index values (DIV) are presented to provide an understanding of the timber sale structure at the mean of 1.4 and one unit changes around it. Unfortunately the small number of sales in the data with a diversity index value of 0.4 made a one unit decrease difficult to represent. To present an approximation of the timber sales with low index values, sales having a diversity index of 0.3 to 0.5 were averaged. Shaded regions in each matrix correspond to categories that had average volume and thus contributed to the index calculation.

Table 2: Average volumes by category of the diversity index (DIV). Averages are of all timber sales occurring in a specific index value. The five grade categories are on the left-hand side of the matrices and the eight species categories are listed in order of dominance across the top of the matrices.

Diversity Index Value 0.3-0.5									
	1	2	3	4	5	6	7	8	Totals
P, 2P, 3P, SM, #1S	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%
#2S	24.9%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	25.0%
#3S	62.3%	2.3%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	64.9%
#4S	9.2%	0.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.8%
#5S	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	96.7%	3.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	100%
Diversity Index Value 1.4									
	1	2	3	4	5	6	7	8	Totals
P, 2P, 3P, SM, #1S	3.5%	0.3%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	3.9%
#2S	39.5%	6.9%	0.8%	0.2%	0.1%	0.0%	0.0%	0.0%	47.4%
#3S	30.4%	9.0%	1.8%	0.6%	0.2%	0.0%	0.0%	0.0%	42.0%
#4S	2.9%	2.8%	0.7%	0.2%	0.1%	0.0%	0.0%	0.0%	6.7%
#5S	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	76.2%	19.0%	3.3%	1.1%	0.3%	0.1%	0.0%	0.0%	100%
Diversity Index Value 2.4									
	1	2	3	4	5	6	7	8	Totals
P, 2P, 3P, SM, #1S	2.2%	1.5%	0.3%	0.9%	0.2%	0.7%	0.0%	0.0%	5.8%
#2S	16.7%	10.2%	4.2%	2.6%	1.5%	1.0%	0.5%	0.0%	36.9%
#3S	14.6%	7.3%	7.5%	3.9%	2.9%	1.0%	0.3%	0.0%	37.6%
#4S	5.6%	6.0%	3.4%	2.4%	1.8%	0.4%	0.2%	0.0%	19.8%
#5S	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Totals	39.1%	25.0%	15.5%	9.7%	6.5%	3.0%	1.0%	0.1%	100%

Table 2 provides a rough depiction of what a one unit increment of DIV corresponds to in this dataset. It is evident that as the index increases the volume is being distributed over a larger portion of the matrix. Increases to the index value appear to be driven by increases in the distribution of volume among species. The grade characteristic of the index does not appear to be driving the index value as much as the species characteristic.

To empirically answer the question of whether sawtimber diversity among species or grade classification had a greater impact on the market value of timber sales in the data, two additional models were estimated. In model 6 the species variable previously defined was substituted for the diversity variable. In model 7 the grade variable previously defined was substituted for the diversity variable. Table 3 displays the results of models 5, 6 and 7. Models 5 and 6 both display coefficients weighted for heteroscedasticity. Since weighted coefficients were estimated after verifying the significance of the variables in an unweighted estimate, the output of model 7 is unweighted. Due to the insignificance of the grade variable, weighted coefficients for model 7 were not pursued.

Table 3: Estimation output for models 5 through 7. Bolded values are coefficients. Values in italics are t-statistics. * P<= 0.01, ** P<=0.10, *** P>0.25, all other P-values are equal to 0.00.

	Model 5	Model 6	Model 7
DIV	-53928.05		
	-29.12		
SPECIES		-65454.08	
		-36.76	
GRADE			-32359.27
			-1.05***
NBID	36713.23	38562.75	36949.47
	49.01	49.46	6.05
NBID^2	-1369.66	-1476.34	-1326.45
	-23.06	-22.59	-2.56*
ACRES	-670.95	-613.98	-511.53
	-45.70	-43.46	-4.17
ACRES^2	-0.32	-0.39	-0.61
	-16.28	-14.01	-5.46
RDCON	-1109.66	-1255.88	-1166.98
	-42.41	-40.03	-7.24
RDRECON	-316.55	-268.29	-319.47
	-25.34	-21.68	-4.91
VS1DF	644.75	623.29	626.78
	99.96	72.50	12.20
VS1DF^2	0.10	0.10	0.10
	9.87	10.37	3.26
VS2DF	361.59	371.41	366.80
	142.32	118.09	25.71
VS2DF^2	-0.01	-0.01	-0.01
	-7.11	-8.84	-2.57*
VS3DF	318.16	295.02	301.39
	86.68	50.18	11.04
VS3DF^2	-0.03	-0.02	-0.02
	-15.95	-5.56	-1.80**
VS1WH	956.95	935.43	984.20
	53.12	43.33	12.74
VS2WH	229.31	230.36	221.18
	70.91	57.38	10.52
VS3WH	120.59	119.27	116.74
	36.31	39.08	7.11
OVOL	254.16	251.84	231.99
	126.04	119.39	25.34
OVOL^2	-0.0006	-0.0003	0.0036
	-2.56*	-1.11***	3.22
DFP	3787.23	3812.79	3868.64
	177.79	154.16	16.95
Adjusted R-squared	0.86	0.86	0.86

GRADE, which represents the distribution of volume among only the five grade classifications, was not found to be significantly different from zero. SPECIES, which represents the distribution of volume among only the eight possible species categories, was found to be significantly different from zero. This estimation reported an increase of one unit of SPECIES as resulting in a loss of $65,454 to market value. Since this variable has a possible range from 0 to 2.08 it is readily apparent that a one unit change is, like that of DIV, large and abstract. Table 4 represents what a one unit change in SPECIES looks like in the data. The mean of the species index was 0.7. Unfortunately no sales had an index value of 1.7 so a one unit increase from the mean was not possible. However, a one unit increase in the species index from 0.2 to 1.2 is shown in Table 4.

Table 4: Average volumes by category of the Species index (SPECIES). Averages are of all timber sales occurring in a specific index value. The eight species categories are listed in order of dominance.

Species Index Value	**0.2**	**0.7**	**1.2**
Species 1	95.2%	70.3%	50.8%
Species 2	3.1%	24.6%	26.5%
Species 3	1.5%	3.2%	14.5%
Species 4	0.2%	1.4%	6.0%
Species 5	0.0%	0.3%	1.7%
Species 6	0.0%	0.1%	0.4%
Species 7	0.0%	0.0%	0.1%
Species 8	0.0%	0.0%	0.0%
Douglas fir	82.4%	56.1%	40.1%
Western Hemlock	11.0%	20.1%	19.9%
Other Species	6.7%	23.8%	40.0%

Table 4 clearly shows the large changes in the distribution of sale volume among greater numbers of species as SPECIES increases. In analyzing the dominant and co-dominant species with respect to all others it is clear that as SPECIES increases the volumes of Douglas fir are decreasing significantly. The percentage of Douglas fir volume reduces from approximately 82 percent in a sale with a species index value of 0.2 to approximately 40 percent in a sale with a species index value of 1.2. The average percent volume of Western Hemlock increases from approximately 11 percent in sales with a species index value of 0.2 to approximately 20 percent in sales having a species index value at the mean of 0.7. From the mean to an index value of 1.2 little change is observed in the average percentages of Western Hemlock. The average percent volumes of other species are clearly increasing significantly with increases in SPECIES. A sale with a species index of 0.2 has on average 6.7 percent of its volume in species other than Douglas fir and Western Hemlock. With a one unit increase in the species index value the percent of volume of other species jumps to approximately 40 percent.

Since the species and diversity index are unitarily different by definition, the elasticity of each was calculated at the mean in order to directly compare their effect on market value. The elasticity of the diversity index at the mean was -0.10. This is interpreted as a one percent increase in the diversity index resulting in a 0.10 percent loss in market value. The elasticity of the species index at the mean was -0.06, in other words, a one percent increase in the species index resulted in a 0.06 percent loss in market value. As elasticities are directly comparable it was concluded that the diversity index had the greatest effect on market value. The grade index was insignificant and therefore it was concluded that the distribution of volume among species in a timber sale has a greater effect than the distribution of volume among the grade classifications of this study. However the fact that the diversity index had the greatest impact on the market value implied that although grade class diversity by itself showed no effect on market value, grade diversity is important in combination with species classifications as the diversity index measures the distribution of volume across both species and grade categories.

MULTICOLLINEARITY

Further study into the presence of multicollinearity is needed. A correlation matrix was created of all independent variables to check for pairwise correlation among explanatory variables. A correlation coefficient of 0.8 or higher was determined significant evidence of pairwise collinearity among explanatory variables. All correlation coefficients returned by the correlation matrix were less than 0.8 and thus, no evidence was found of collinearity among pair wise correlation coefficients of the independent variables. However, this does not rule out the presence of multicollinearity. A high correlation among explanatory variables can result in biased coefficients and may lead to insignificance of explanatory variables known to be important in explaining the dependent variable. Insignificance of explanatory variables was not an issue of this study. However, formal tests of multicollinearity were not pursued. This is an area in which further study would be beneficial.

DISCUSSION

Analysis of WA DNR timber sale history provided some interesting indications regarding the sale attributes or characteristics affecting final sale value in western Washington from January 1989 through May 2005. Multiple regression equations were used to examine the effect of sawtimber diversity on the market value or final timber sale value of DNR lump sum Board sales. The theoretical assumptions of the final model were based on a hedonic price equation in which a timber sale was defined as differentiated factors of production associated with the products produced from timber. The final model contained both linear and quadratic terms for the independent variables

The final model returned the hypothesized coefficients for all independent variables with the exception of the variable for total acreage. The impacts of indices representing sawtimber diversity were of particular interest. These variables provide interesting information regarding DNR lump sum sales in western Washington.

The diversity variable included in the model is an index calculation performed on each timber sale in the dataset to provide a measure of heterogeneity across both species and sawtimber grades. Heterogeneity is defined as a measure of the distribution of volume among sawlog grade and tree species. Increasing levels of this type of sawtimber heterogeneity were predicted to negatively impact the final sale value of DNR timber sales in western Washington. This prediction was based on similar results regarding timber sales of the U.S. South, particularly North Carolina (Boltz et al. 2002). Empirical analysis showed strong evidence that sawtimber diversity among species and grade classifications negatively impacted the final sale value. Increasing variability of volume among tree species was found to negatively impact the final sale value more than increasing variability of volume among grade classifications.

A possible reason for this result is that commodity producers generally focus on a tree species or a certain range of grade classes. For instance a sawmill may be best geared to mill #2 and #3 sawlogs, or perhaps a commodity producer uses only Douglas fir in the manufacture of its products. Increasing heterogeneity of sawtimber in a lump sum framework forces these bidders to bid on greater volumes that they are not interested in and may in fact have to resell. This is believed to be viewed negatively by bidders as an additional cost of production.

This study has important implications for silvicultural management on state lands in Washington. The multi-purpose management plan adhered to by the DNR demands silvicultural practices on some properties that will result in a large degree of variability among both sawlog grades and tree species. Greater knowledge of the financial ramifications provide the DNR with more information to better assess the costs and benefits associated with timberland management on individual properties and the influence those properties have on annual revenues generated by state landholdings overall. In this manner, the findings of this study could be used as a decision tool. Should the DNR encounter situations where they need to conduct timber sales from a tract of land containing a high level of sawtimber diversity, the recommendation would be that they consider ways to try and mitigate the negative impacts that high levels of sawtimber diversity can have on the market value of a lump sum sale. Possibilities include investigating the use of a different sale method or dividing the sale into smaller sales of less heterogeneous sawtimber.

In addition to the effect of sawtimber diversity, this study found significant evidence that an increased pool of bidders and therefore increased competition for a timber sale had a positive impact on the market value. In examining the raw data over the time period of study it is apparent that there has been a downward trend in the average number of bidders (Figure 9). In 1989 the average number of bidders on a given timber sale was approximately 10. By 2004 the average number of bidders had decreased to approximately 4 and, although 2005 is only partially represented in the data, this downward trend in competition appears to have continued into the first half of 2005.

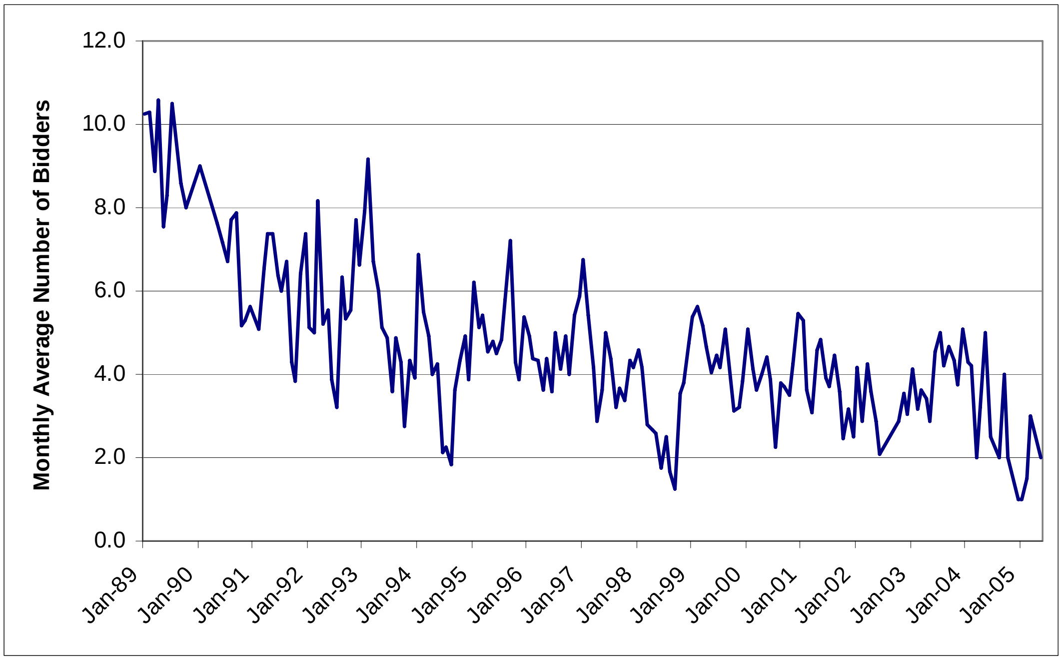

Figure 9: Monthly averages of the number of bidders involved in Western Washington DNR timber sales of the dataset. 2005 averages are only though May of 2005.

SUGGESTIONS FOR FUTURE RESEARCH

This study had two important contributions which can be generalized to lump sum timber sales from DNR lands in western Washington. This study determined that increasing levels of heterogeneous sawtimber lowered the final timber sale value on lump sum DNR sales in western Washington. It also determined that competitiveness among bidders on these timber sales has been decreasing over the time period of study. A number of beneficial future research areas stem from these conclusions.

Further research comparing the effects of sawtimber diversity with respect to sale method would allow the DNR to assess whether timber sales with higher levels of sawtimber heterogeneity should be marketed differently. By expanding the contract harvest method or creating a similar method for larger sales the DNR may be able to increase revenues on more heterogeneous timber sales. Specifically, this type of research would benefit from analysis of what bundles of timber might be most attractive to bidding firms.

The total acreage of timber sales in the study region displayed diseconomies of scale. While this result was not predicted, it is not uncommon in the literature. Munn and Rucker (1995) and Boltz et al. (2002) both found significant evidence that parcel size negatively impacts final sale value. However, this variable presents a clear focus for future study to explore why increasing parcel size results in reduced final sale value in western Washington. In understanding the implications of this variable it is important to consider who purchases DNR timber and industry shifts over the period of study.

DNR marketing studies conducted in the late nineties defined the DNR's marketing area as commodity producers located in Washington and Oregon. Export restriction eliminated international trade markets and transportation cost hampered the development of other domestic markets (Shramek 1999). Within Washington and Oregon large commodity producers, having multiple processing facilities and producing multiple products, were found to be best serviced by the DNR (Shramek and Nicholas 1998). These large commodity producers were predominately sawmills and demanded large, stable supplies of timber. These producers were considered to have a competitive advantage over smaller commodity producers in bidding on DNR timber sales due to the large scale of many DNR sales.

Over the study period the Washington sawmilling industry experienced a great deal of turmoil related to the volatility in timber supply previously mentioned. This contributed to a restructuring of Washington's sawmill industry that resulted in consolidation down to approximately 75 sawmills. As of 2002 over half of these mills were Class A sawmills with the capacity to produce over 120,000 board feet of lumber per 8 hour shift (Perez-Garcia et al. 2005).

A declining pool of bidders, structural changes to Washington's forest industry, and issues related to the demand for stumpage are all factors that may be related to the diseconomies of scale associated with the model's total acreage variable. Further empirical work in this area would contribute to a better understanding of the DNR timber sale program.

Research regarding how the DNR could increase the number of bids offered on its timber sales without altering its methods of sale would also be valuable. Increasing the pool of bidders on a timber sale pushes the final sale value closer to the true market value. While increasing the competition among bidders is a good way of increasing the timber revenues annually generated by the DNR's timber sale program, mill consolidation in the state of Washington suggests that there may not be a lot of room for this to occur. Additionally, the DNR would not want to adversely impact strong relationships it has developed with large commodity producers. They represent a steady demand for the states timber as well as important sources of employment. Future market research is needed to determine the feasibility and impact of attempts to improve competitiveness on DNR timber sales.

CONCLUSIONS

There is evidence that the final value of DNR timber sales located in western Washington were negatively influenced by increases in the level of sawtimber heterogeneity over the period of study. Heterogeneity among tree species was found to impact final sale value more than heterogeneity among sawlog grades. The impacts of sawtimber heterogeneity were not well serviced by the lump sum method of timber sale. Timber sales in which greater levels of sawtimber diversity are observed may return greater revenues to the DNR if another method of sale is instituted. Additional empirical work on heterogeneous timber sales focusing on how the DNR can create bundles of timber from these sales attractive to different bidders would be pertinent.

The level of competitiveness declined over the period of study. The existence of a competitive framework among bidding firms is a key to achieving a final timber sale value at or near market value. Declines in the average number of bidders on timber sales in the data set may be caused by a number of factors. Regardless, these declines are cause for alarm and further research into why they are occurring and what can be done to alleviate the impacts.

BIBLIOGRAPHY

American Forest & Paper Association. Wood Statistical Roundup. Washington, DC. Various issues.

Bare, BB and Smith RL. (1999) Estimating Stumpage Values from Transaction Evidence Using Multiple Regression. Journal of Forestry, Volume 97, No. 7: 32-39 (July 1999)

Boltz, F; Carter, DR; Jacobson, MG. (2002) Shadow pricing diversity in U.S. national forests. Journal of Forest Economics 8: 185 - 197.

Buongiorno, J; Dahir, S; Lu, H; Lin, C. (1994) Tree Size Diversity and Economic Returns in Uneven-Aged Forest Stands. Forest Science, Volume 40, No. 1: 83-103 (February 1994).

Buongiorno, J; Peyron, J; Houllier, F; Bruciamacchie, M. (1995) Growth and Management of Mixed-Species, Uneven-Aged Forests in French Jura: Implications for Economic Returns and Tree Diversity. Forest Science, Volume 41, No. 3: 397-429 (August 1995).

Carter, DR and Newman, DH. (1998) The impact of reserve prices in sealed bid federal timber sale auctions. Forest Science 44: 485 – 495.

Daniels, Jean M. (2005) The Rise and Fall of the Pacific Northwest Log Export Market. USDA Forest Service Gen. Tech. Rep. PNW-GTR-624. February 2005.

Ehrenreich, John H. (1991) A Transaction Evidence Stumpage Appraisal Model for the Idaho Department of Lands Clearwater Area. Master’s Thesis. College of Forestry, Wildlife and Range, University of Idaho, Moscow, ID.

Greene, WH. (2003) Econometric analysis, 5th Ed. Prentice-Hall, Upper Saddle River, NJ.

Haynes, RW. (1980) Competition for National Forest Timber in the Northern, Pacific Southwest, and Pacific Northwest Regions. USDA Forest Service Research Paper PNW-266. January 1980.

Hotvedt, J. (1999) Timber Sales Appraisal System. Unknown publication explaining the WA DNR approach to transaction evidence appraisal.

Huang, MF and Buongiorno, J. (1986) Market value of timber when some offerings are not sold: implications for appraisal and demand analysis. Forest Science. 32: 845 – 854.

Huebschmann, MM; Lynch, TB; Lewis, DK; Tilley, DS; Guldin, JM. (2004) A Bid Price Equation for National Forest Timber Sales in Western Arkansas and Southeastern Oklahoma. Southern Journal of Applied Forestry, Volume 28, No. 2: 100-108.

Ingram, CD and Buongiorno, J. (1996) Income and Diversity Tradeoffs from Management of Mixed Lowland Dipterocarps in Malaysia. Journal of Tropical Forest Science, Volume 9, No. 2: 242-270 (March 1996).

Ladd, GW and Martin, MB. (1976) Prices and Demands for Input Characteristics. American Journal of Agricultural Economics, Volume 58, No. 1: 21-30 (February 1976).

Leffler, KB and Rucker, RR. (1991) Transaction Costs and the Efficient Organization of Production: A Study of Timber-Harvesting Contracts. The Journal of Political Economy, Vol. 99, No.5: 1060-1087. (Oct., 1991)

Lippke, HL. (1994) The Economic Effects of the Forest Resources Conservation and Shortage Relief Act on Timber Prices. Reprint 25A, Center for International Trade in Forest Products, College of Forest Resources, University of Washington, Seattle, WA (May 1994).

Mason, LC. (2005) An Examination of the Washington Department of Natural Resources Timber Sale Program Against a Backdrop of Changing Regional Infrastructure and a Growing Forest Health Crisis. Rural Technology Initiative, Working Paper 2, College of Forest Resources, University of Washington, Seattle. April 2005.

Munn, IA and Palmquist, RB. (1997) Estimating hedonic price equations for a timber stumpage market using stochastic frontier estimation procedures. Canadian Journal of Forest Resources, 27: 1276-1280 (April 1997).

Munn, IA and Rucker, RR. (1995) An Economic Analysis of the Differences Between Bid Prices on Forest Service and Private Timber Sales. Forest Science, Volume 41, No. 4: 823-840 (November 1995).

Munn, IA and Rucker, RR. (1998) Predicting Forestry Consultant Participation Based on Physical Characteristics of Timber Sales. Journal of Forest Economics, Volume 4, No. 2: 105-124.

Perez-Garcia, J; Barr, JK; Daniels, J. (2005) Washington's Sawmilling Sector Analysis: Capacity Utilization Rates and Timber Outlook. Working Paper 99, Center for International Trade in Forest Products, College of Forest Resources, University of Washington, Seattle, WA (September 2005).

Perez-Garcia, J. and Barr, JK. (2005) Forest Products Export Trends Update for the Pacific Northwest Region. Northwest Environmental Forum, College of Forest Resources, University of Washington. November 2005.

Puttock, GD; Prescott, DM; Meilke, KD. (1990) Stumpage Prices in Southwestern Ontario: A Hedonic Function Approach. Forest Science, Volume 36, No. 4: 1119-1132 (December 1990).

Rosen, S. (1974) Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. The Journal of Political Economy, Volume 82, No. 1: 34-55 (January-February 1974).

Sendak, PE. (1991) Timber sale value as a function of sale characteristics and number of bidders. Research Paper NE-657, USDA Forest Service, Northeastern Forest Experiment Station, Radnor, PA.

Shramek, J and Nicholas, G. (1998) Timber Marketing Strategy Plan for the Washington State Department of Natural Resources. Washington State Department of Natural Resources, Forest Resources Division, Marketing and Program Development Section. Olympia, Washington (August 1998).

Shramek, J. (1999) Implementing the Strategic Timber Marketing Plan: PNW Timber-Processing Industry Segment Analysis and Recommended Target Segments. Washington State Department of Natural Resources, Forest Resources Division, Marketing and Program Development Section. Olympia, Washington (March 1999).

U.S. Census Bureau. New Privately Owned Housing Units Started, Annual Data. U.S. Census Bureau, July 14, 2005 < http://www.census.gov/const/startsan.pdf>

Washington State Department of Natural Resources. Washington Timber Harvest Report. Olympia, Washington. Various years.

Washington State Department of Natural Resources. Washington Mill Survey. Olympia, Washington. Various years.

Washington State Department of Natural Resources. (1997) Final Habitat Conservation Plan. Olympia, Washington. September 1997.

Western Wood Products Association. PNW Coast Lumber Price Index. Portland, Oregon. Various issues.

APPENDIX

Table 5: Model 1

Dependent Variable: MV

Sample: 1 2194

Included observations: 2194

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DIV	-59218.05	12950.74	-4.572560	0.0000
NBID	21587.10	1938.101	11.13828	0.0000
ACRES	-1084.296	73.78104	-14.69614	0.0000
CL	-1109.061	643.5445	-1.723364	0.0850
RDCON	-978.9432	161.4806	-6.062296	0.0000
RDRECON	-264.6392	65.25919	-4.055202	0.0001
VS1DF	769.5885	25.91961	29.69136	0.0000
VS2DF	337.0095	7.110886	47.39346	0.0000
VS3DF	282.4479	13.83394	20.41702	0.0000
VS1WH	976.1007	77.56763	12.58387	0.0000
VS2WH	220.5913	20.90281	10.55319	0.0000
VS3WH	135.0560	16.28547	8.293036	0.0000
OVOL	258.0587	6.249366	41.29359	0.0000
DFP	3765.907	227.1368	16.57991	0.0000
Constant	-869626.2	62530.65	-13.90720	0.0000

R-squared	0.853500	**Mean dependent var**	749144.5
Adjusted R-squared	0.852558	**S.D. dependent var**	585769.9
S.E. of regression	224924.7	**Akaike info criterion**	27.49173
Sum squared resid	1.10E+14	**Schwarz criterion**	27.53066
Log likelihood	-30143.43	**F-statistic**	906.7627
Durbin-Watson stat	1.526674	**Prob(F-statistic)**	0.000000

Table 6: Model 2

Dependent Variable: MV

Sample: 1 2194

Included observations: 2194

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DIV	-58965.17	12955.76	-4.551270	0.0000
NBID	21525.29	1938.645	11.10327	0.0000
ACRES	-1095.166	73.54418	-14.89126	0.0000
RDCON	-985.9778	161.5019	-6.105052	0.0000
RDRECON	-271.1964	65.17760	-4.160883	0.0000
VS1DF	768.6843	25.92601	29.64916	0.0000
VS2DF	336.5566	7.109237	47.34074	0.0000
VS3DF	281.3509	13.82553	20.35009	0.0000
VS1WH	974.8779	77.59942	12.56295	0.0000
VS2WH	221.7372	20.90167	10.60859	0.0000
VS3WH	133.1986	16.25711	8.193254	0.0000
OVOL	256.7238	6.203974	41.38054	0.0000
DFP	3712.783	225.1369	16.49122	0.0000
Constant	-881259.1	62193.33	-14.16967	0.0000

R-squared	0.853300	Mean dependent var	749144.5
Adjusted R-squared	0.852425	S.D. dependent var	585769.9
S.E. of regression	225026.3	Akaike info criterion	27.49218
Sum squared resid	1.10E+14	Schwarz criterion	27.52851
Log likelihood	-30144.92	F-statistic	975.4038
Durbin-Watson stat	1.529434	Prob(F-statistic)	0.000000

Table 7: Model 3

Dependent Variable: MV
Sample: 1 2194
Included observations: 2194
Weighting series: 1/RESID4

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DIV	-60614.76	1346.025	-45.03241	0.0000
NBID	22076.63	251.8335	87.66362	0.0000
ACRES	-1093.841	13.54959	-80.72865	0.0000
RDCON	-957.6255	16.91158	-56.62544	0.0000
RDRECON	-258.1867	8.218173	-31.41656	0.0000
VS1DF	769.7026	3.467723	221.9620	0.0000
VS2DF	335.8591	1.201017	279.6456	0.0000
VS3DF	279.7129	1.676335	166.8598	0.0000
VS1WH	1034.251	40.14556	25.76252	0.0000
VS2WH	224.6264	2.882161	77.93679	0.0000
VS3WH	130.1913	1.889562	68.90024	0.0000
OVOL	256.6147	0.513930	499.3189	0.0000
DFP	3698.847	25.28532	146.2843	0.0000
Constant	-877165.0	6939.129	-126.4085	0.0000

	Weighted Statistics		
R-squared	0.997206	Mean dependent var	644899.9
Adjusted R-squared	0.997189	S.D. dependent var	3102233.
S.E. of regression	55499.58	Akaike info criterion	24.69250
Sum squared resid	6.71E+12	Schwarz criterion	24.72883
Log likelihood	-27073.67	F-statistic	59842.01
Durbin-Watson stat	1.761328	Prob(F-statistic)	0.000000

	Unweighted Statistics		
R-squared	0.853224	Mean dependent var	749144.5
Adjusted R-squared	0.852349	S.D. dependent var	585769.9
S.E. of regression	225084.2	Sum squared resid	1.10E+14
Durbin-Watson stat	1.530381		

Table 8: Model 4

Dependent Variable: MV
Sample: 1 2194
Included observations: 2194
Weighting series: 1/RESID4

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DIV	-187194.6	9222.825	-20.29689	0.0000
DIV2	48054.00	3069.615	15.65473	0.0000
NBID	40266.54	696.4634	57.81573	0.0000
NBID2	-1661.791	68.25019	-24.34852	0.0000
ACRES	-704.1371	20.47471	-34.39057	0.0000
ACRES2	-0.355830	0.023543	-15.11424	0.0000
RDCON	-1164.716	10.76818	-108.1628	0.0000
RDRECON	-309.3330	12.65565	-24.44228	0.0000
VS1DF	640.3009	8.184284	78.23542	0.0000
VS1DF2	0.117770	0.009626	12.23466	0.0000
VS2DF	361.4417	2.432029	148.6173	0.0000
VS2DF2	-0.006859	0.000847	-8.098014	0.0000
VS3DF	316.4609	3.506789	90.24235	0.0000
VS3DF2	-0.023682	0.001306	-18.13288	0.0000
VS1WH	986.2988	20.63562	47.79593	0.0000
VS2WH	222.2473	4.296061	51.73281	0.0000
VS3WH	128.8001	2.172438	59.28826	0.0000
OVOL	254.7916	1.217109	209.3417	0.0000
OVOL2	-0.000125	0.000248	-0.505681	0.6131
DFP	3718.649	24.42600	152.2415	0.0000
Constant	-882951.9	8058.857	-109.5629	0.0000

Weighted Statistics

R-squared	0.999442	Mean dependent var	702166.3
Adjusted R-squared	0.999437	S.D. dependent var	7816070.
S.E. of regression	52160.10	Akaike info criterion	24.57155
Sum squared resid	5.91E+12	Schwarz criterion	24.62604
Log likelihood	-26933.99	F-statistic	194480.3
Durbin-Watson stat	1.720912	Prob(F-statistic)	0.000000

Unweighted Statistics

R-squared	0.857073	Mean dependent var	749144.5
Adjusted R-squared	0.855758	S.D. dependent var	585769.9
S.E. of regression	222471.0	Sum squared resid	1.08E+14
Durbin-Watson stat	1.492108		

Table 9: Model 5

Dependent Variable: MV
Sample: 1 2194
Included observations: 2194
Weighting series: 1/RESID4

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DIV	-53928.05	1851.824	-29.12159	0.0000
NBID	36713.23	749.0915	49.01035	0.0000
NBID2	-1369.658	59.40111	-23.05778	0.0000
ACRES	-670.9539	14.68259	-45.69724	0.0000
ACRES2	-0.324731	0.019943	-16.28271	0.0000
RDCON	-1109.662	26.16808	-42.40516	0.0000
RDRECON	-316.5508	12.49031	-25.34370	0.0000
VS1DF	644.7457	6.450187	99.95768	0.0000
VS1DF2	0.098832	0.010016	9.867387	0.0000
VS2DF	361.5908	2.540601	142.3249	0.0000
VS2DF2	-0.006955	0.000978	-7.111108	0.0000
VS3DF	318.1598	3.670654	86.67661	0.0000
VS3DF2	-0.025577	0.001603	-15.95410	0.0000
VS1WH	956.9460	18.01349	53.12385	0.0000
VS2WH	229.3135	3.233886	70.90960	0.0000
VS3WH	120.5888	3.320845	36.31267	0.0000
OVOL	254.1591	2.016553	126.0364	0.0000
OVOL2	-0.000571	0.000223	-2.555433	0.0107
DFP	3787.232	21.30179	177.7894	0.0000
Constant	-977126.3	6111.603	-159.8805	0.0000
	Weighted Statistics			
R-squared	0.999673	Mean dependent var		599212.5
Adjusted R-squared	0.999670	S.D. dependent var		3810341.
S.E. of regression	48919.25	Akaike info criterion		24.44280
Sum squared resid	5.20E+12	Schwarz criterion		24.49470
Log likelihood	-26793.76	F-statistic		349866.7
Durbin-Watson stat	1.699192	Prob(F-statistic)		0.000000
	Unweighted Statistics			
R-squared	0.856587	Mean dependent var		749144.5
Adjusted R-squared	0.855334	S.D. dependent var		585769.9
S.E. of regression	222797.6	Sum squared resid		1.08E+14
Durbin-Watson stat	1.495354			

Table 10: Model 6 - After an unweighted model estimation confirmed significance of all independent variables, this weighted version was produced.

Dependent Variable: MV
Sample: 1 2194
Included observations: 2194
Weighting series: 1/RESID4

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SPECIES	-65454.08	1780.650	-36.75854	0.0000
NBID	38562.75	779.7250	49.45687	0.0000
NBID2	-1476.336	65.34474	-22.59303	0.0000
ACRES	-613.9761	14.12769	-43.45904	0.0000
ACRES2	-0.387953	0.027699	-14.00601	0.0000
RDCON	-1255.880	31.37686	-40.02567	0.0000
RDRECON	-268.2901	12.37535	-21.67939	0.0000
VS1DF	623.2905	8.597449	72.49715	0.0000
VS1DF2	0.102077	0.009842	10.37206	0.0000
VS2DF	371.4080	3.145012	118.0943	0.0000
VS2DF2	-0.008932	0.001011	-8.836921	0.0000
VS3DF	295.0175	5.879288	50.17911	0.0000
VS3DF2	-0.016919	0.003041	-5.562720	0.0000
VS1WH	935.4317	21.59049	43.32611	0.0000
VS2WH	230.3575	4.014271	57.38464	0.0000
VS3WH	119.2676	3.052075	39.07756	0.0000
OVOL	251.8431	2.109397	119.3911	0.0000
OVOL2	-0.000293	0.000263	-1.113006	0.2658
DFP	3812.787	24.73288	154.1586	0.0000
Constant	-1023015.	6771.499	-151.0766	0.0000

Weighted Statistics

R-squared	0.999454	Mean dependent var	598985.0
Adjusted R-squared	0.999449	S.D. dependent var	3329295.
S.E. of regression	55334.31	Akaike info criterion	24.68925
Sum squared resid	6.66E+12	Schwarz criterion	24.74115
Log likelihood	-27064.11	F-statistic	209281.1
Durbin-Watson stat	1.723228	Prob(F-statistic)	0.000000

Unweighted Statistics

R-squared	0.857069	Mean dependent var	749144.5
Adjusted R-squared	0.855820	S.D. dependent var	585769.9
S.E. of regression	222422.8	Sum squared resid	1.08E+14
Durbin-Watson stat	1.499488		

Table 11: Model 7 - Due to the insignificance of GRADE in this unweighted estimation, a weighted estimation was not conducted.

Dependent Variable: MV

Sample: 1 2194

Included observations: 2194

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GRADE	-32359.27	30743.83	-1.052545	0.2927
NBID	36949.47	6107.877	6.049479	0.0000
NBID2	-1326.447	517.6484	-2.562449	0.0105
ACRES	-511.5267	122.6919	-4.169196	0.0000
ACRES2	-0.607686	0.111308	-5.459507	0.0000
RDCON	-1166.977	161.0935	-7.244098	0.0000
RDRECON	-319.4727	65.04731	-4.911390	0.0000
VS1DF	626.7811	51.38345	12.19811	0.0000
VS1DF2	0.099083	0.030389	3.260468	0.0011
VS2DF	366.8046	14.26623	25.71140	0.0000
VS2DF2	-0.007500	0.002923	-2.566219	0.0103
VS3DF	301.3902	27.29494	11.04198	0.0000
VS3DF2	-0.015931	0.008855	-1.799029	0.0722
VS1WH	984.2015	77.26378	12.73820	0.0000
VS2WH	221.1788	21.01852	10.52304	0.0000
VS3WH	116.7429	16.41050	7.113914	0.0000
OVOL	231.9920	9.156034	25.33761	0.0000
OVOL2	0.003587	0.001114	3.221036	0.0013
DFP	3868.637	228.1764	16.95459	0.0000
Constant	-1045326.	70259.11	-14.87816	0.0000

R-squared	0.856459	Mean dependent var	749144.5
Adjusted R-squared	0.855204	S.D. dependent var	585769.9
S.E. of regression	222897.2	Akaike info criterion	27.47588
Sum squared resid	1.08E+14	Schwarz criterion	27.52778
Log likelihood	-30121.04	F-statistic	682.7104
Durbin-Watson stat	1.497338	Prob(F-statistic)	0.000000